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A TECHNICAL JOURNAL FOR DESIGNERS AND USERS OF ELECTRICAL, ELECTRONIC, HYDRAULIC, MECHANICAL AND PNEUMATIC CONTROL SYSTEMS AND INSTRUMENTATION

CONTROL

SYSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

VOL. 3 NO 23 MAY 1960

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LOOKING FOR A JOB? CONTROL *carries the best jobs going in instrument and control engineering.* **SEE PAGE 264 AND ONWARDS**

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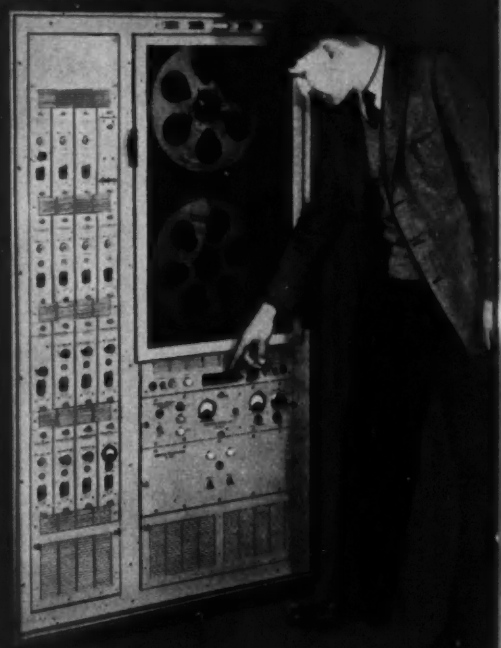

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Specialised control and instrumentation equipment has been developed by Sperry for nuclear reactors. Major examples of this work are included on the Sperry stand at Olympia.

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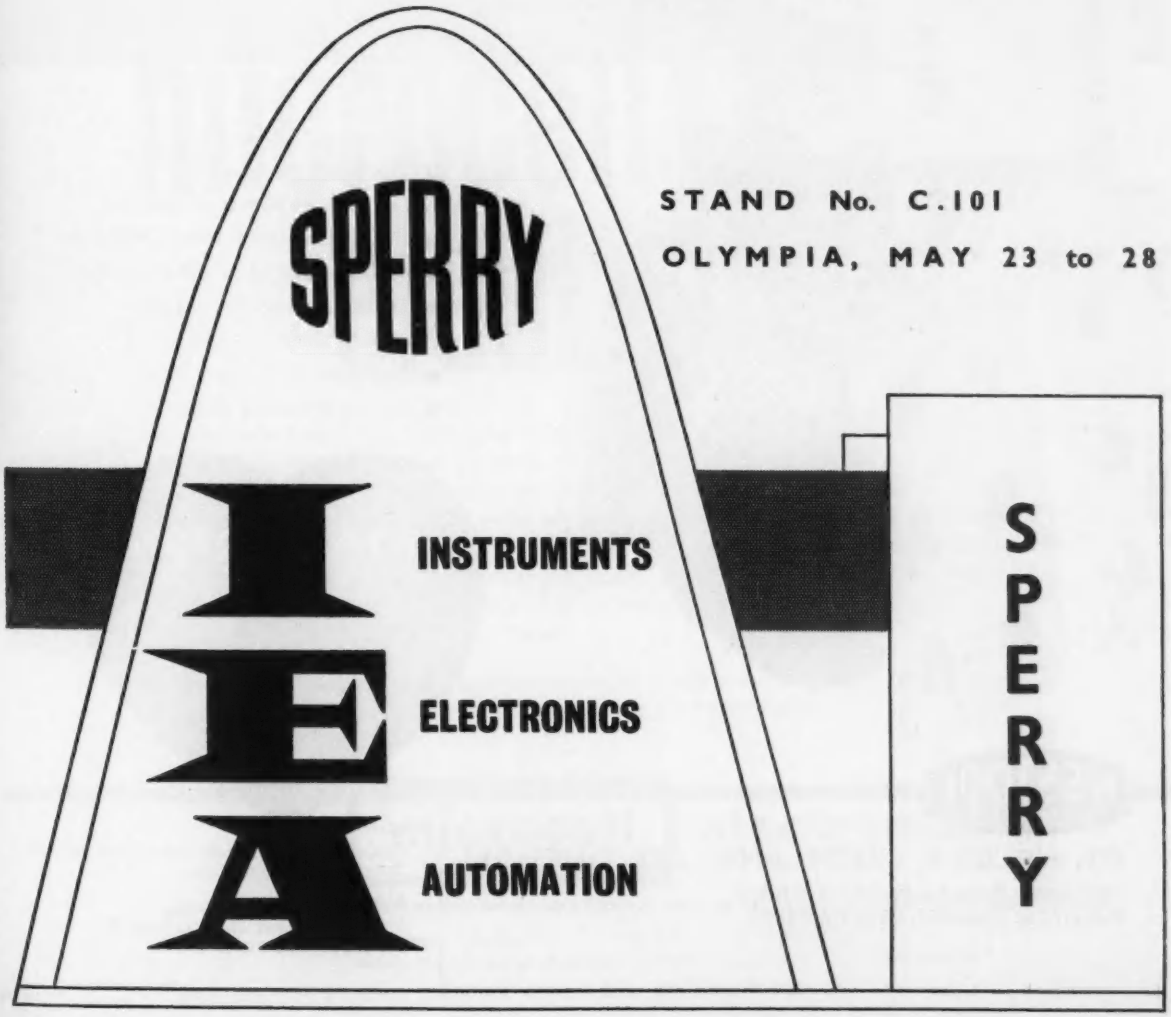

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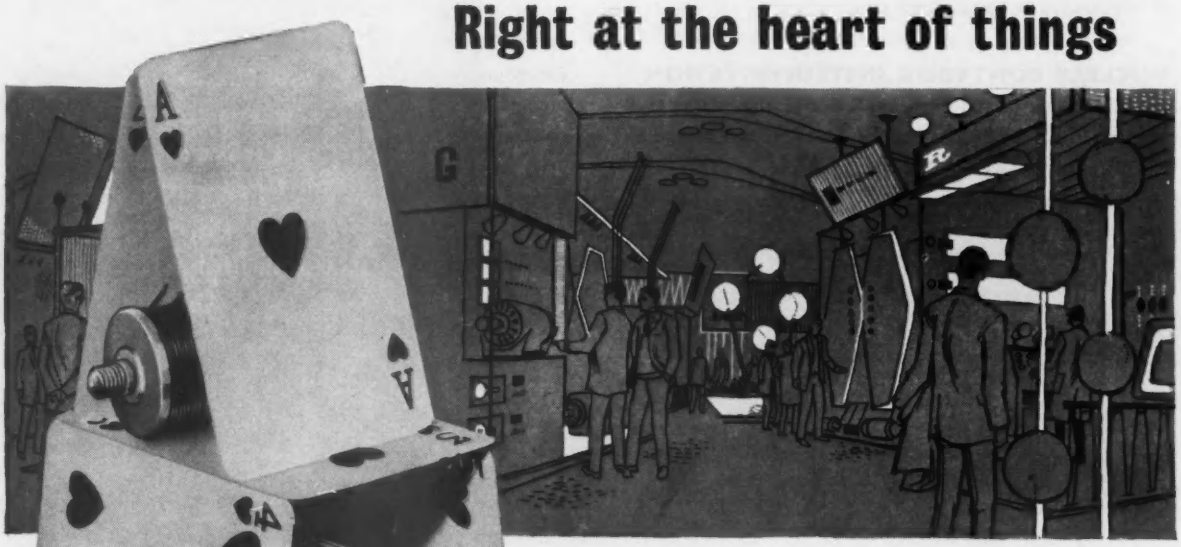

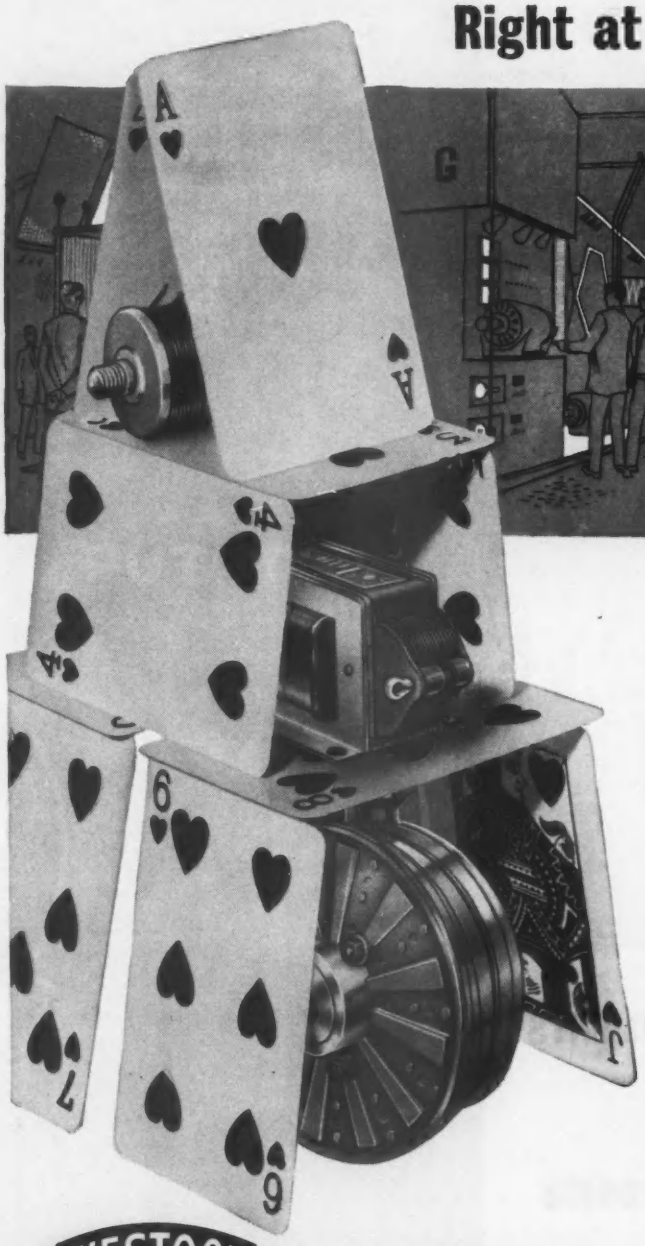

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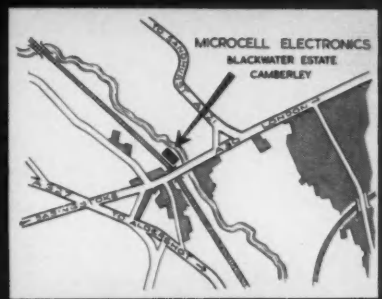

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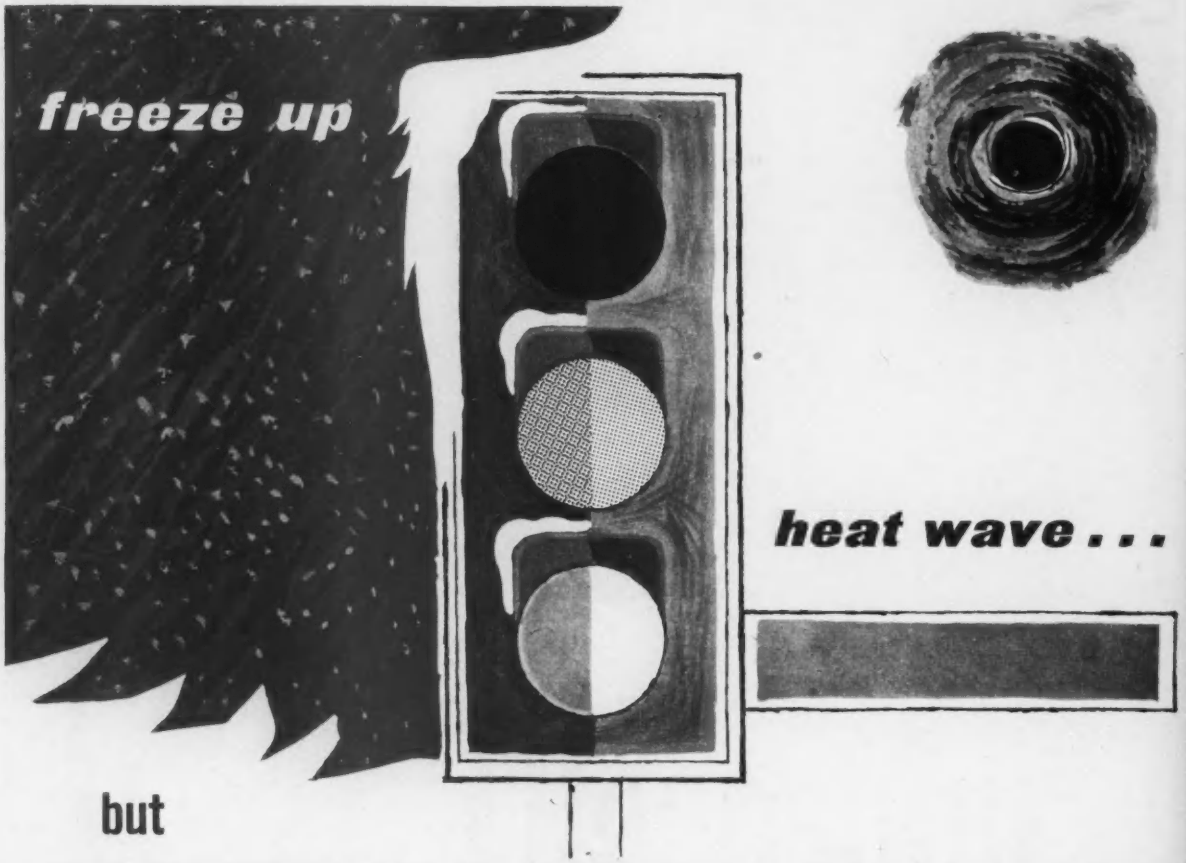

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FORD

£10 million 48 acre paint trim and assembly plant—
SQUARE D gear controls vital 10 miles of flow line

Square D plays a key part in this new plant—the most advanced of its type to-day. Its selective conveyor system was designed and installed by Geo. W. King Ltd. in co-operation with Ford engineers.

One of the two control rooms which tracks and controls the movement of car bodies on the automatic transfer system through the paint shop. All breaks and changes in flow are registered and conveyor speeds regulated from this Square D panel.

Square D was specified for the plant's complex range of automatic flow line operations. Two central control rooms, together with several local consoles designed and built by Square D, supervise the entire handling system. Hundreds of Square D 2-unit push button stations and limit switches are heavily worked in this up-to-the-minute example of automation in the motor industry.

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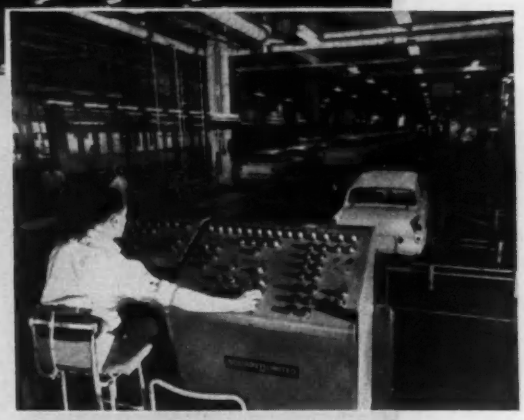

Local consoles sited throughout the plant supplement the two central control rooms. Here the transfer between primer and final enamel sections is supervised.

The system of indexers regulates the flow of bodies over the conveyor bridge and into twin storage lines before the phosphating process. Each line of 11 bodies is fed alternately by automatic selection.

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Modern electronic equipment is too delicate to face even normal travel hazards. Unless it is scientifically packed and cushioned many thousands of pounds worth of work and effort can be rendered useless.

The Hairlok Laboratories have every facility for studying, planning, designing, testing and constructing every form of special packaging using Hairlok as a basic cushioning material specially moulded to firmly hold and protect your product.

Hairlok is the finest rubberised hair, and is the most suitable material for electronic packaging purposes. It can be moulded in any density to meet the most stringent specifications and can be combined with individually constructed outers to withstand the rigours of all forms of handling and transit.

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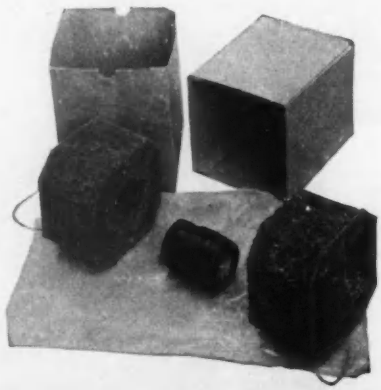
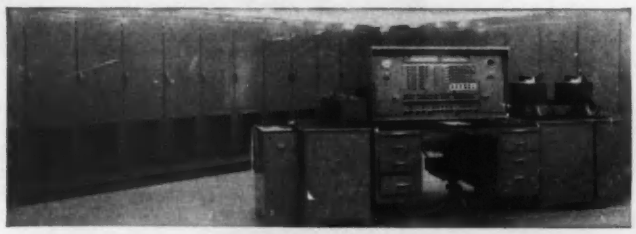
Simple HAIRLOK cushioning for an expensive item of equipment with its tailor-made box.



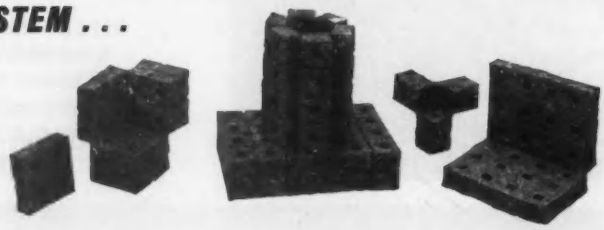
TO COMPLETE COMPUTOR

Complicated data-processing equipment like this National Elliott System has been successfully packed with HAIRLOK for transportation to the other side of the world.



THE ECONOMICAL ATLAS SYSTEM . . .

. . . consists of a range of standard modules or units which can be combined in many simple ways to protect a variety of shapes and sizes. Some of the modules and the shapes that can be accommodated are shown here.



For literature and further details, write or phone:

THE Hairlok COMPANY LTD. Magna Works, Kathie Road, Bedford. Tel. Bedford 4271

the microcell electronic supervisor

The data logger can be arranged to have upper and lower pre-setable controls available on every channel, and no output is effected by tape or printer until any one of the quantities being monitored wanders outside the prescribed set limits. Should all the readings return inside limits, then the machine will automatically note the time and cease recording. Prediction that an event is about to occur is possible because limits can be set closer than the process under control demands.

SPECIFICATION

Number of channels: Type A 12 – 12; " A 24 – 24; " A 48 – 48; " A 96 – 96

Sampling rate – 160 milliseconds per channel.
Maximum decimal digit output rate – 25 per second.
Output code – International Teleprinter, or to order. Analogue to digital overall accuracy – better than ± 0·1%. Input resistance – 1 megohm.

POWER REQUIREMENTS

Normal 240V. A.C. single phase 50 cycles at 1.5 kW.
Alternative 110V. D.C. (converter extra).
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Stand C 108 I.E.A. Exhibition

New Selector

DEKATRON *

GS10G

simplifies multi-stage bi-directional counting

Multi-tube bi-directional counting has always been an involved and expensive procedure requiring the use of many components and careful circuit design. The need for this facility has become increasingly apparent with current developments in electronic weighing, machine tool control, shaft position indicating, computing and similar techniques.

In these and allied fields the answer to multi-stage, bi-directional counting is the GS.10.G—the latest addition to the well-known Dekatron range.

Incorporating "routing guides" to provide glow-direction sensing, inter-decade coupling becomes simple and requires no gating.

Readout can be made directly from glow position as in other Dekatrons but for ideal remote presentation we recommend one of the Digitron register tube series.

Increased ruggedness, even greater reliability and smaller size are additional design features which will appeal to the "electronics" designer.

PROVISIONAL DATA

Max. Counting Rate	10 kp/s
Max. Anode Current	900 μA
Max. Output Pulse with 68K Ω cathode load	35 v
Double Pulse Drive — Amplitude... ...	— 100 v
Double Pulse Drive — Duration	30 μs

See us on Stand D153 at the I.E.A. exhibition, Grand Hall, Olympia from May 23rd—May 28th

Enquiries should be addressed to:-
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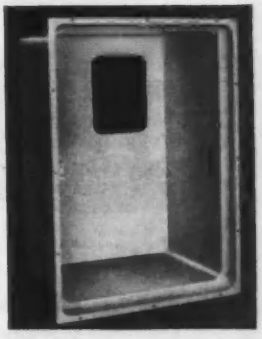
PLASTICS

The liners of modern refrigerators are moulded complete in one operation in high impact polystyrene. The injection moulding machines used in these operations are, it is claimed, the biggest built in the United Kingdom, and employ Vickers-Armstrongs "VSG" variable delivery pumps. Developments in the Plastics Industry continue at an ever increasing tempo, with new methods and machinery continuously being evolved to improve manufacturing standards and to increase the scope of moulding techniques. The use of these pumps in this highly specialised industry is a further example of the many and varied applications of "VSG" equipment which have been serving modern industry for over fifty years.



Moulded for Frigidaire by Ekco Plastics on Windsor AP335 machine.

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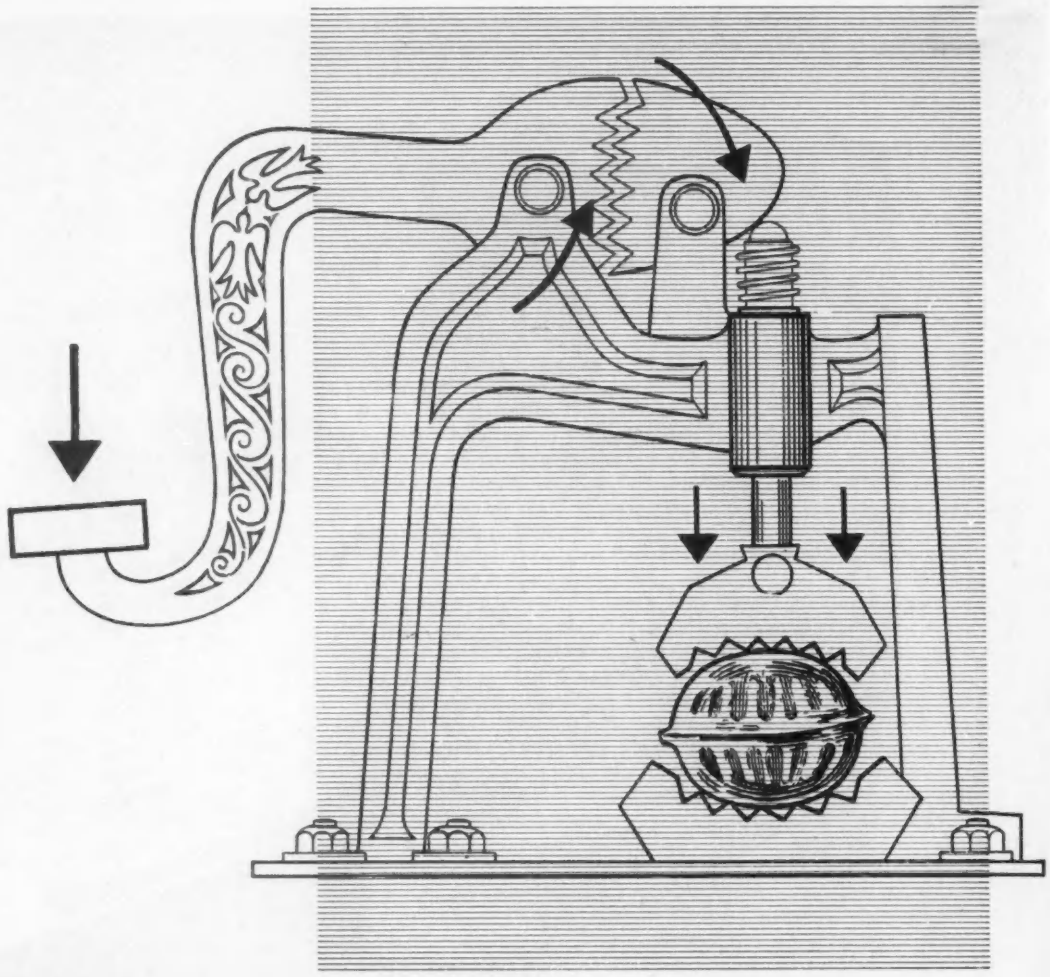
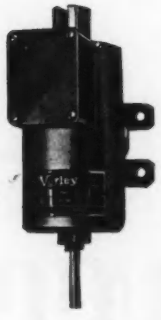


all this to crack a nut!

A machine to crack a nut, any nut, any size, any thickness of shell—a bit unwieldly perhaps, a bit heavy, but it would positively do the job. Inventors of yesterday, with all their technical limitations, often showed surprising ingenuity in overcoming their mechanical problems.

Varley REGD TRADE MARK

SOLENOIDS



Today, when the problems are so much more complicated, the solution is often much simpler—get in touch with Varley's. If your problem is pushing, pulling, punching, prodding, at a distance or automatically, the answer, proved many times in many fields, is a Varley Solenoid.

Type 'C.M.' *(Illustrated)*

A robustly constructed solenoid for industrial applications, supplied to pull or thrust 3 lbs. to 32 lbs. through ¼" to 2¾", depending on rating. Can be supplied with built-in Terminal Box and Contact Cooled Rectifiers for continuous rating on most A.C. Voltages. This range is C.S.A. approved.

For full details of Varley Solenoids, write for Illustrated Catalogue S.3.

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one of the world's smallest SILICON DIODES

MULLARD OA202

Generously rated
Wide temperature range
High back resistance
Ideal for automatic wiring
Rugged construction
ECONOMICALLY PRICED

SILICON

Despite its extremely small size, the Mullard Silicon Junction Diode OA202 will handle peak currents of up to 250 mA at 25°C. Apart from other favourable electrical and mechanical characteristics, the OA202 is distinguished by its cost which is kept at the lowest possible level by very large scale production.

This all-glass diode is hermetically sealed and really is a rugged device. It is made in exactly the same way as the Government Type Approved CV7040, whose rigorous specification includes temperature cycling, climatic cycling, fatigue and shock tests, 1000 hour life tests and high temperature storage.

Brief electrical data is given below. For further information please contact Mullard House.

Abridged Data (at 25°C unless otherwise stated)

Max. peak inverse voltage	150 V
Max. peak forward current	250 mA
Max. d.c. forward current	160 mA
*Average forward current (sinusoidal input with resistive load)	80 mA
Typical forward voltage drop at 30 mA	0.9 V
Inverse current at −150 volts:	
Maximum at 25°C	0.1 μA
Maximum at 125°C	10 μA
Ambient temperature range	−55 to +125°C

**Max. averaging time 50 millisecs.*

(An alternative type, OA200, is available for lower voltage applications.)

See Mullard Semiconductor Devices on Stand M 559 at the INSTRUMENTS, ELECTRONICS AND AUTOMATION EXHIBITION

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industrial semiconductors

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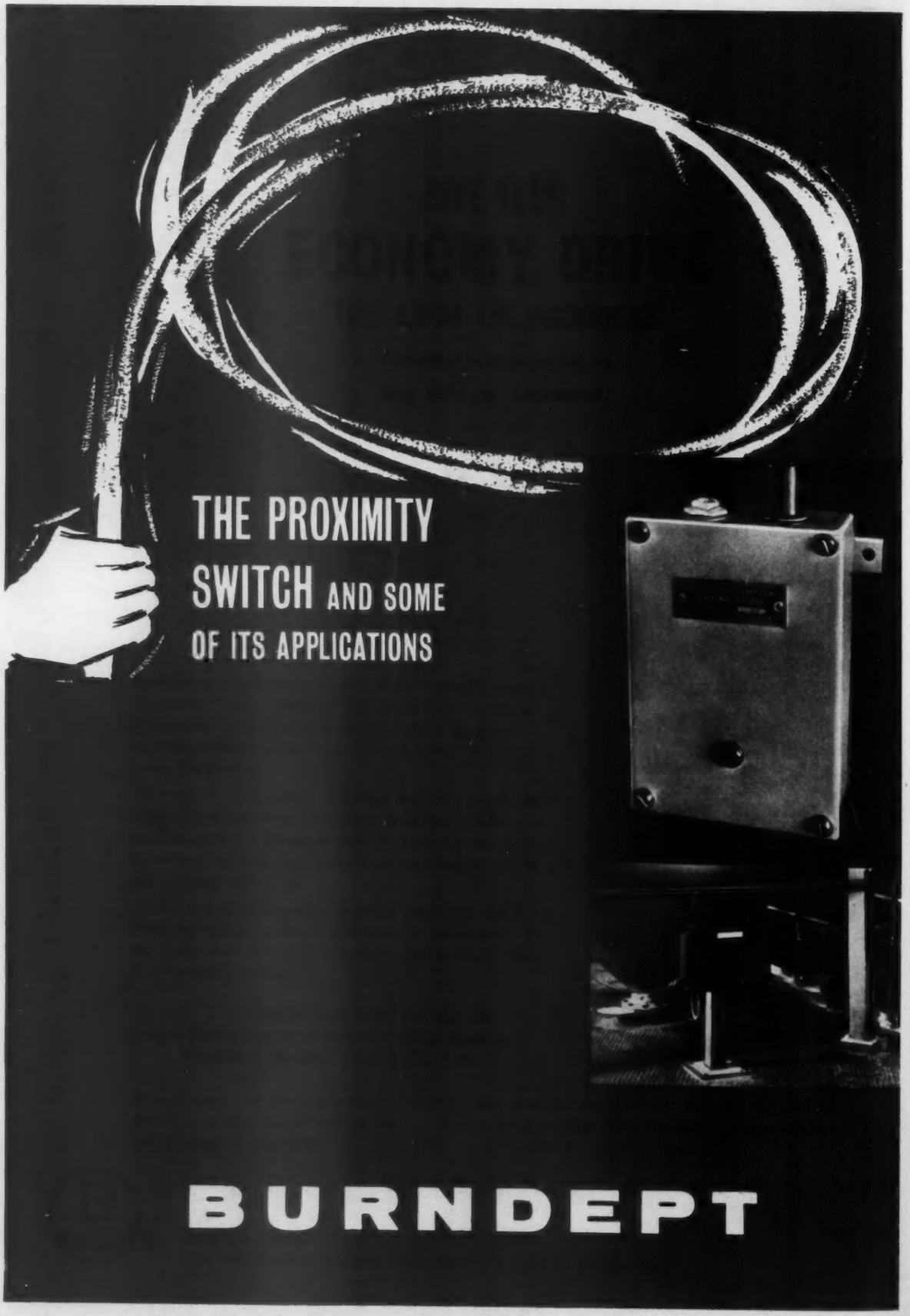

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Electrical Aids in Industry *Data Sheet* **No. 8**

Light-Sensitive Cells

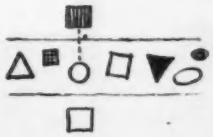
What are light-sensitive cells? They are devices which can sense and measure changes in the level of light or, in some cases, respond to the quality of light falling on them. There are various types of cell and each has its particular field of use. One of the best known is the photo-electric cell.

What can light-sensitive cells do? A change in the amount of light falling on the cell can cause a switch, relay or counter to operate. Alternatively, the direct indication of the light intensity can often allow some other factor to be determined and, if required, controlled. They are reliable and require little maintenance. Careful installation, as with all types of equipment, gives a good reward.

How can they be used? These cells have many applications in industry, for controlling processes, for inspection and measurement, for sorting material and for safety purposes:

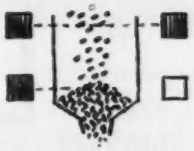
Counting

Where objects on a conveyor belt are too soft or light to operate a direct mechanical counting device, where they are too delicate or freshly painted to sustain physical contact or where the articles vary in size, a light-sensitive cell can be used. This counts the objects by interruption of an appropriately sited beam of light.



Hopper or Tank Level Control

Many forms of feed can be accurately controlled by light cells. One important one is for controlling the input to a hopper of fluid solids such as sand or peas. Here, two horizontal light beams are required: the upper, when interrupted, indicates that the hopper is full and stops the supply; the lower, when it ceases to be interrupted, indicates that the hopper is nearly empty and restarts the flow.



Package Content

The level of powder in packages can be checked with light cells. The cell is so positioned that when the powder is up to the required level, the light reflected from the surface of the powder is picked up by the cell and causes the carton to be accepted. If not, it is rejected.

Colour Sorting

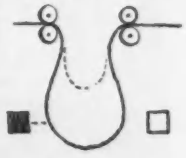
The quality of many articles can be gauged by their colour—seeds and nut kernels, for instance. The objects are fed into a tube by means of a vibrator pan and fall into the beams of three equally spaced light cells which scan them from all sides. If the object is acceptable it falls into a chute carrying it to one conveyor; if its colour is bad it is deflected as a reject.

Guillotine Guard

Light cells for guarding a guillotine or power press should be used only as a supplement to a mechanical guard or where the latter is impracticable. The interruption of a curtain of light by a hand stops the machine instantaneously.

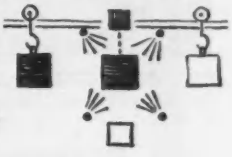
Press Feeding

Where the rate of feed of strip metal must be suited to a varying speed of acceptance by a press, a loop of the strip is allowed to sag between the feed and the press. When the loop reaches a predetermined depth a light beam is interrupted and the slack is taken up.



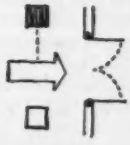
Processing Objects on the Move

Many articles are processed while on a conveyor line. For instance, where articles are to be sprayed while on the conveyor, the paint saved by stopping the gun between articles will make the device worthwhile. The same principle applies in a bakery to the spraying of baking tins with fat.



Automatic Door Opening and Closing

Doors can be caused to open or close by the interruption of a beam of light. This has its uses in such cases as control of doors on a heating oven or for the passage of vehicles in a factory. This is effected by a light beam on the side from which the approach is made (in many cases, both). When the approach beam is interrupted it opens the door which closes again after a given time interval.



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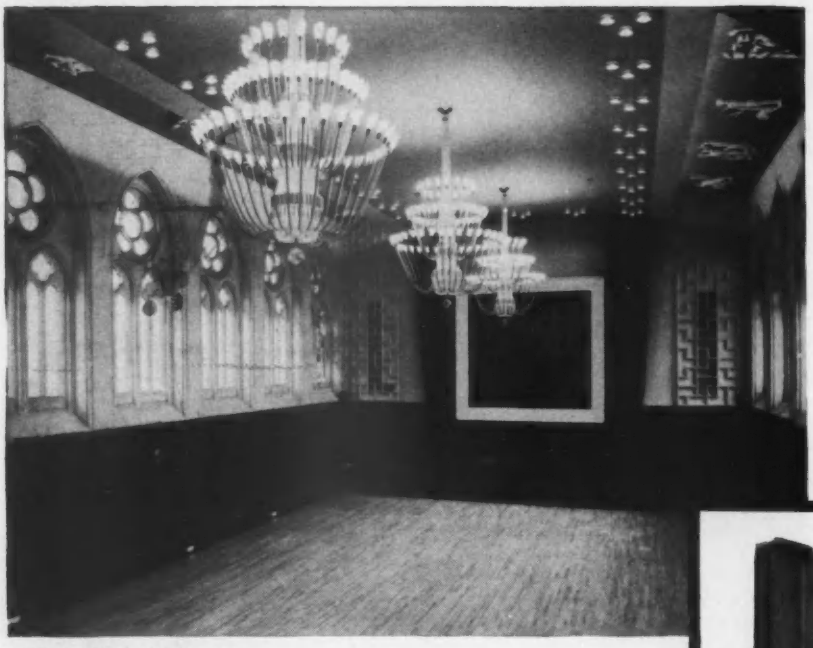
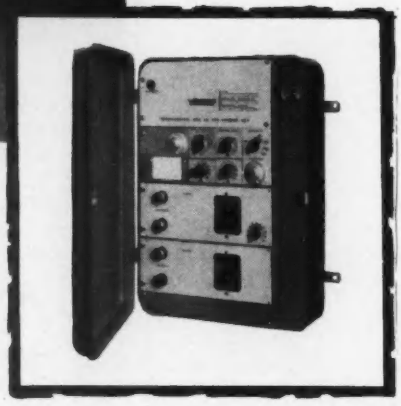
electronic control yet again provides the answer



PLYMOUTH GUILDHALL
Consulting Engineers: Hoare Lea & Partners



The Ventonik electronic temperature control equipment installed at the re-built Plymouth Guildhall illustrated above represents the use of the most modern techniques of control including the use of thermistors and 'thermal reset' for plant anticipatory action.
With the minute size and the tremendous mechanical strength of the thermistor it was possible to position these in the base of the magnificent chandeliers ensuring the most accurate points for the detection of temperature change for the accurate control of comfort throughout the Guildhall.
Using printed circuit technique, plug-in amplifiers and thermistor detection units, with the styling by an industrial designer, the Ventonik units represent the finest electronic control system currently available.
Installation is superbly simple and the inter-connecting wiring can be of standard form without shielding.
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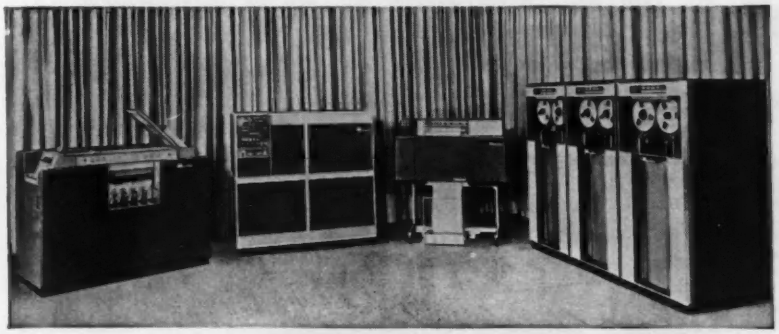
success story



Seven months ago we announced an entirely new small computer with very fast input and output—the IBM 1401 Data Processing System. We were certain that many commercial organisations needed a machine that would bridge the gap between the normal punched card system and the large-scale computer. And we were right. To date over 40 machines (about half of them with magnetic tape units) have been ordered in the United Kingdom, and over 400 in Europe as a whole. The first will be installed in 1961.

who is buying the IBM 1401?

Orders have now been received from the following:—

- * Bank of Scotland
- * Cheshire County Council
- City of Plymouth
- C. & J. Clark Ltd.
- Coty (England) Limited
- Durham County Council
- * Esso Petroleum Company Limited
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- * Lloyd's Policy Signing Office
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- * Shell International Petroleum Company Limited
- Wesleyan and General Assurance Society
- * United Kingdom Atomic Energy Authority

et al.

* *With magnetic tape units*

what jobs will they do?

Here are some of the jobs these IBM 1401 machines will be doing:

Payroll
Stock control
Sales ledger and statements
Invoicing
Statistics
Credit accounting
Production planning
Costing
Insurance – premium accounting and policy recording
Hire purchase accounting
Banking – current accounts
Nuclear research

The IBM 1401 Data Processing System in brief

The basic 1401 system consists of just three units which offer

card reading at up to 800 cards a minute
card punching at up to 250 cards a minute
line printing at up to 600 lines a minute
advanced stored-program calculating and control.

We have designed the system so that you can add up to six magnetic tape units, each with read/write speeds of up to 62,500 characters a second. These equip the machine to deal with a larger volume of work, or enable you to employ large-scale IBM computer systems even more efficiently by passing ancillary operations to this smaller and less expensive machine.
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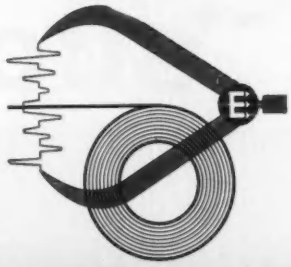

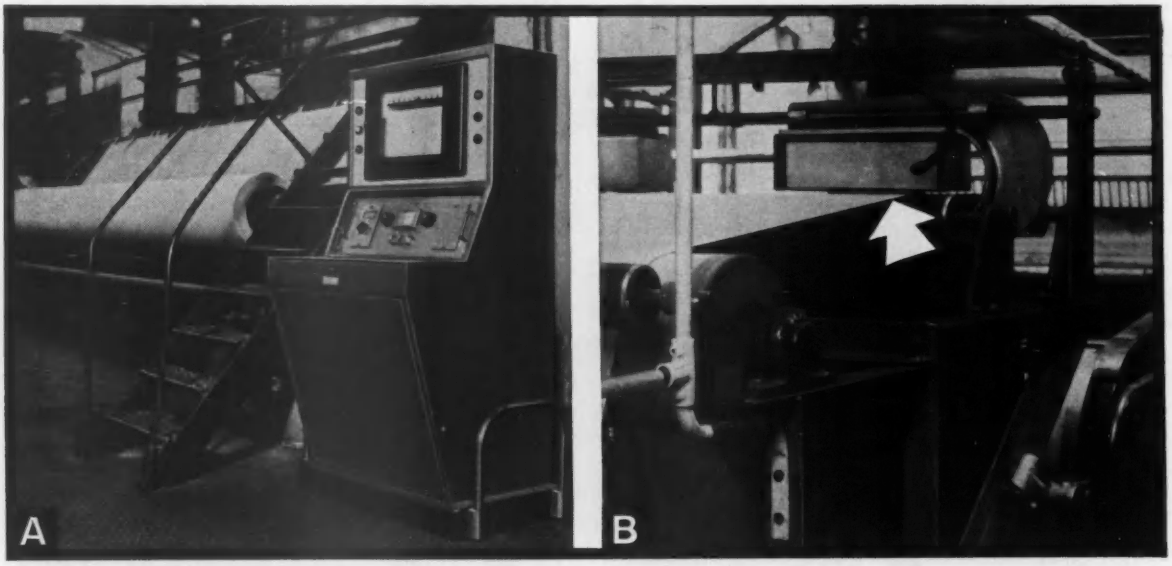

(Photographs by courtesy of the Bowaters Organization and I.C.I Ltd.)

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A. *An Ekco Automatic Standardisation Gauge shows prominently in this front view of the dry end of a 280 in. Fourdrinier Machine producing newsprint.*

B. *Two measuring heads, one on each side of the sheet, are employed in this Ekco Nucleonic Gauge installation. The machine is a Bridges 3-bowl calender, producing PVC coated fabric in one of the largest factories manufacturing leather cloth in Great Britain.*

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EKCO nucleonic gauges

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The "Flometric" is precision engineered to deliver and to maintain one set rate of fluid flow regardless of variable inlet pressures. It is not just a flow retarding device, but a true and accurate flow control. Rated up to 5 g.p.m. Size ⅜" B.S.P.

The "Flometric" is one of seven Birflo controls, each designed to overcome a particular flow problem. Pressure range up to 150 p.s.i.

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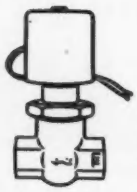

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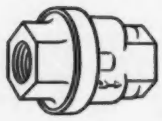
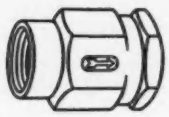
A solenoid valve for maximum flow rates. Sizes up to 1¼" B.S.P.

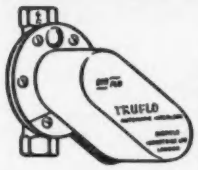
FLOMITE
A direct acting solenoid valve for small flow and volume control. Sizes ¼" and ⅜".



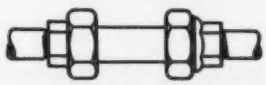
MULTI CONSTAFLO
An accurate metering valve for flow rates up to 86 g.p.m. Sizes ¾" and 1".



CONSTAFLO
A consistent control for flow rates up to 7 g.p.m. Sizes up to ½".



TRUFLO
For positive flow-rate control with minimum 1/10 g.p.m. or maximum 40 g.p.m. limits.



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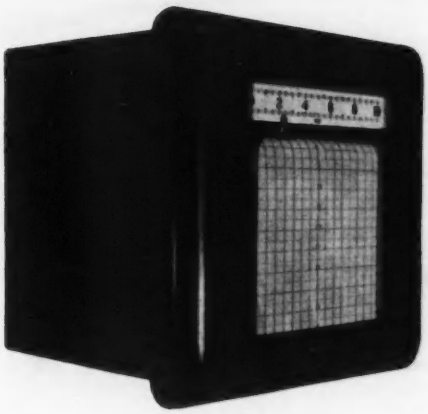
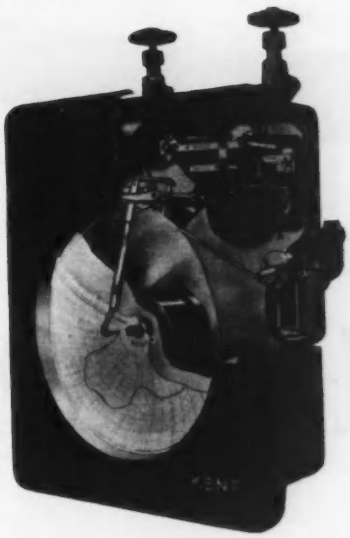


The new electronic **Mark 3 Multelec** instrument, a high-speed (one second or two second full-scale pen travel) indicator-recorder with automatic control optional on certain models; single-point and multi-point measurement; for temperature, O_2, millivoltage, conductivity, etc.



The **Commander** instrument range, with its matching style of presentation and rationalized design to user advantage, offers a wide choice of individual models to meet your measuring requirements.

Examples of further instruments to be made available in the **Commander** range can be seen on the KENT Stand; these include sealed-bell models for low-head differential-pressure measurement, bellows-operated models for static-pressure measurement, float-operated types for open-channel measurement, and additional electronic models such as a precision indicator and a circular-scale controller.

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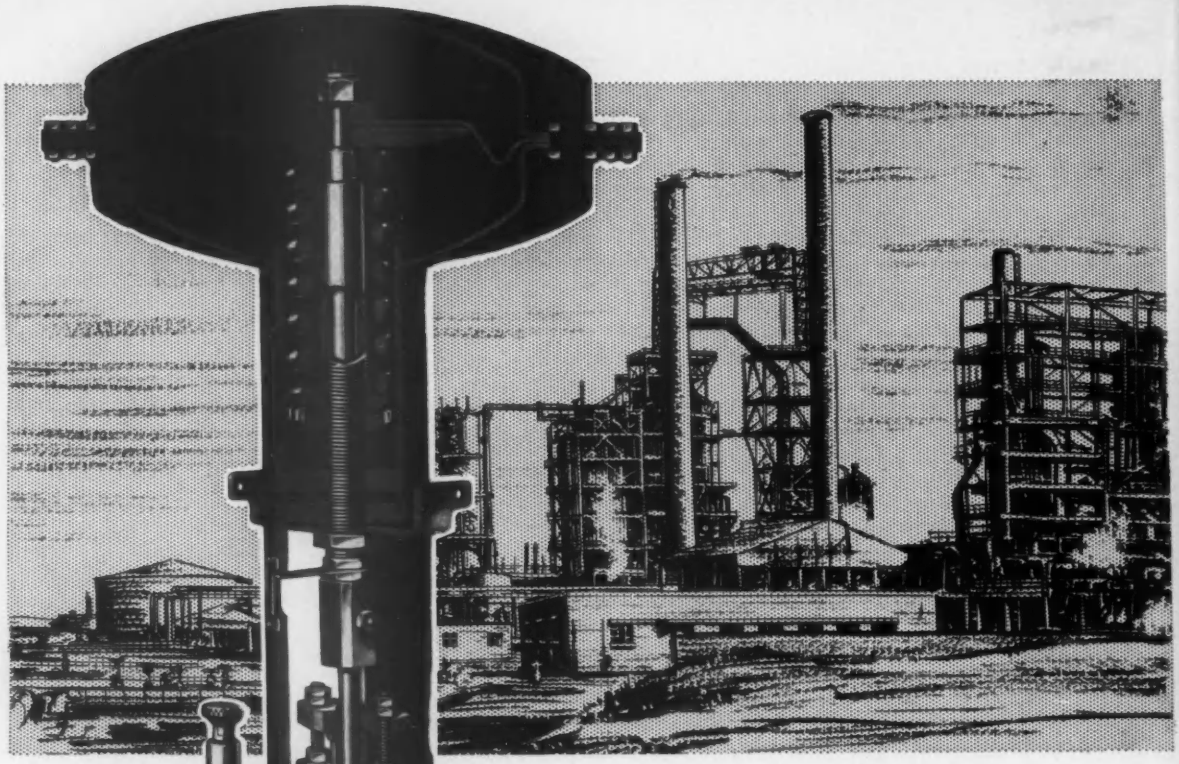

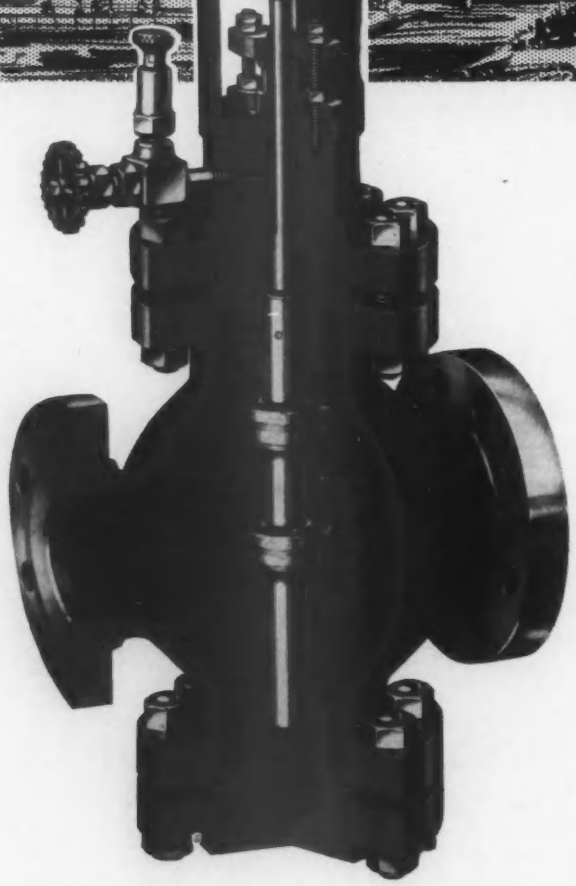

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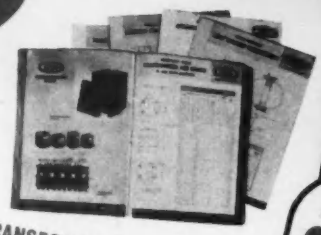

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Westool transformers range from the smallest possible up to 2000 VA for sealed can types and from 5kVA single-phase to 18kVA three-phase.

Transformers and chokes are made to customers' specifications—or designed to meet customers' specific needs.

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Westool coil winding machines include single and multi-coil machines, dual purpose machines and models with push-button control.

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Warner electro-magnetic couplings give cushioned, smooth, instantaneous action. From "inching to full speed"—either forward or reverse—Warner units provide variable control as desired. Automatic take-up for wear eliminates the need for adjustment. 'Pancake' shape occupies minimum of shaft length.

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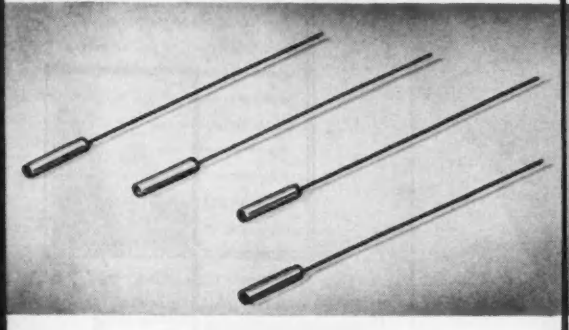
SenTerCel

germanium junction photo-electric cells

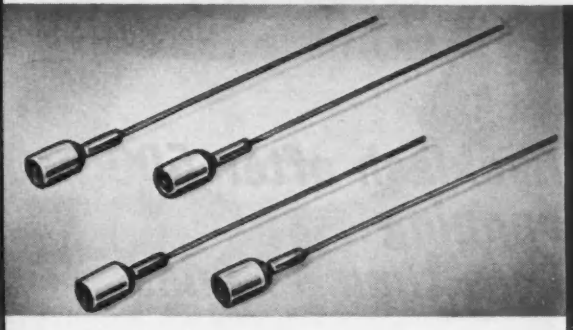
TYPE PG40B



for punched card and punched tape scanning applications

The result of manufacturing development work on the type PG40A, this cell consists of a germanium element with p-n junction parallel to the largest face. The overall diameter is only 0.080" and this reduction in size offers greater facility for mass grouping where the devices are used for scanning punched card and perforated tape.

TYPE PG50A



for machine tool control and industrial counting applications

Characterized by small size and large output. This type has an impedance and output characteristic which enables it to be used with both relays and valve circuits. The cell consists of a germanium element with a p-n junction parallel to the largest face.

Full electrical and spectral characteristics are given in Technical Data Sheets obtainable from:—

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GEARHEADS

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These gearheads are designed to mount on the front of standard Bu-Ord, SAE, and RAE size 11 motors, and can accommodate the different shaft lengths of these types. They have the same overall diameter and mounting arrangements as the motors to enable them to be mounted in a similar manner. Types are available modified for use with size 08 or size 10 motors, or on their own as speed reducers. In the design particular attention has been paid to robust construction and long life, ball bearings are used throughout and the materials and dimensions of the gears have been chosen to give minimum amount of wear.

PERFORMANCE SPECIFICATION

INPUT. The input gear meshes with the 13 tooth 120 DP. pinion of either standard Mark 14 motors, size 11 motors to SAE ARP, 497 or size 11 motors to RAE, EL, 1789. OUTPUT. The standard output shaft is splined 21 teeth 120 DP. with thread for shaft nut and drive washer. Alternatively plain shafts up to $\frac{7}{16}$" diameter may be supplied, or a 13 tooth 120 DP. pinion suitable for cascading 2 or more gearheads.

Maximum power output, torque not to exceed 80 oz in	$\frac{1}{4}$ watt
Maximum backlash after 500 hrs running with $\frac{1}{4}$ watt load	45 minutes measured on output shaft by reversing 8 oz in torque
Starting torque	0 2 gm cm
Inertia at motor shaft	0.02 g cm^2
Operating temperature range	—54°C to +100°C
Tropical exposure test DTD 1085B	Withstands 28 days exposure

RATIOS. A number of ratios up to 600:1 are available as standard and these will probably satisfy most requirements:—Types G11A, 600:1; G11B, 300:1; G11C, 150:1; G11D, 60:1; G11E, 24:1; G11G, 40:1. Other ratios can be provided.

MUIRHEAD

Precision Electrical Instruments

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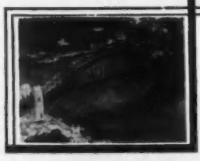

on request

MUIRHEAD

TECHNIQUE

A Journal of Instrument Engineering for Scientists, Engineers, Technicians, Research Workers

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KENT
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384

A
MODERN
MINIATURE

In attractive cases of contemporary design for flush panel mounting, these modern miniature Moving Coil and Moving Iron Ammeters and Voltmeters are compact, robust and possess the same high performance characteristics as larger "Cirscale" Instruments. 3¼ in. square bezel, 2⅝ in. diameter body fits standard K class fixing hole.

RECORD

"CIRSCALE"

SERIES B

Offices at: Belfast, Birmingham, Bristol, Dublin, Glasgow, Leeds, London.

THE RECORD ELECTRICAL CO. LIMITED

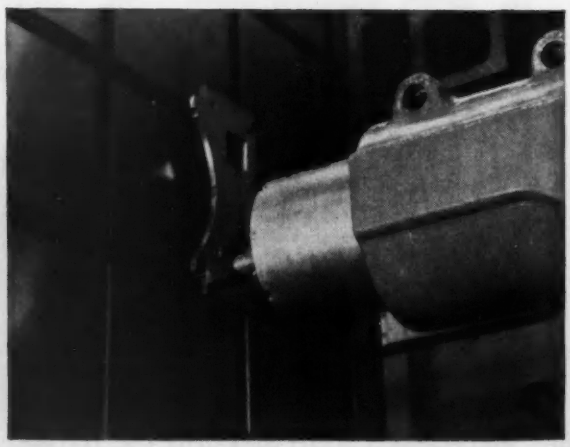
"Cirscale Works", Broadheath, Altrincham, Cheshire.

MACHINE TOOL DESIGNERS AND MANUFACTURERS
TODAY'S—AND TOMORROW'S—TREND IS TO MORE AUTOMATIC CONTROL

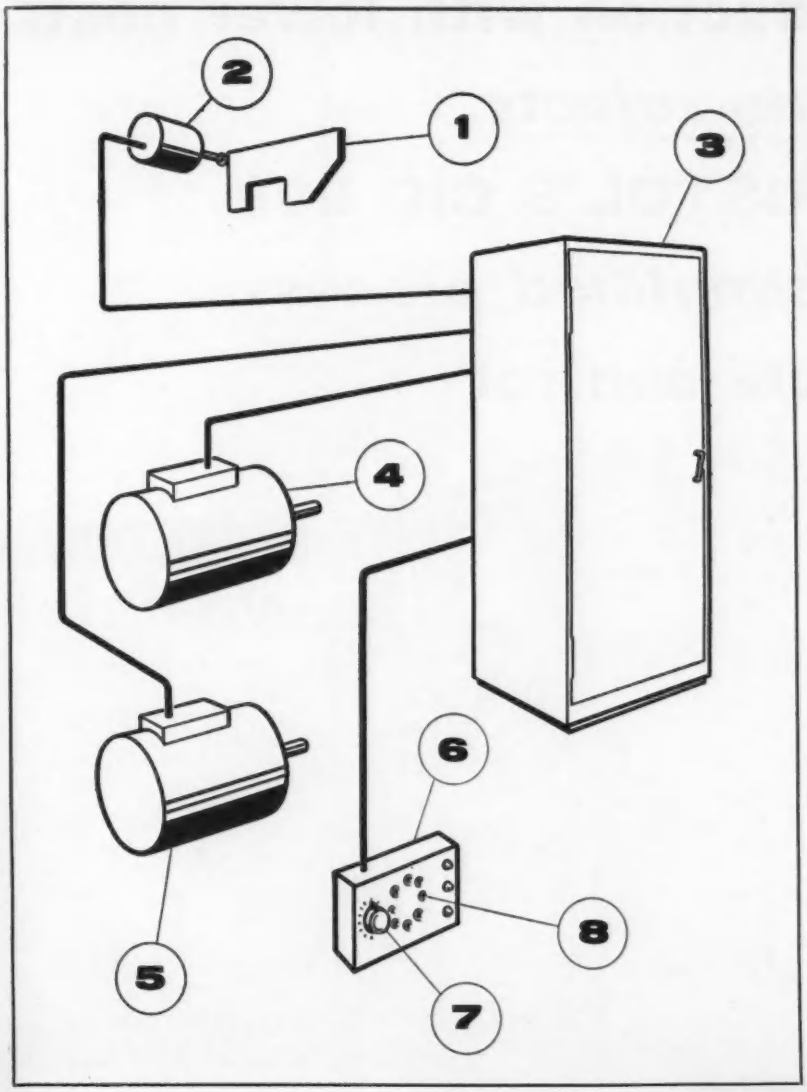
Now—new simplification brings two-axis copying equipment at lowest cost ever

From Britain's most experienced control equipment team—application proved by ten years' operation on numerous types of machine tool—this adaptable equipment opens up new possibilities in machine tool design

Exclusive printed circuit card unit construction brings simplification, standardisation and lower costs



Simple rugged tracer head has single moving part



1. template or model
2. tracer head
3. compact self-contained control cubicle
4. x.—axis high response servo motor of required rating
5. y.—axis high response servo motor of required rating
6. control station [can be suitable for building in]
7. control for profiling speed round work
8. pushbuttons for manual movement direction

In full scale production — hundreds in the field and four equipments a month going to one machine tool manufacturer alone — these equipments are so designed that they can be readily tailored to the requirements of any type of tool — from the largest to the smallest.

As well as being adaptable to single — and multi-axis operation, the system can also be applied to joystick steering control.

For more details write to Special Equipment Division at the address below.

Full scale functional test facilities ensure consistent equipment performance

LANCASHIRE DYNAMO ELECTRONIC PRODUCTS LIMITED

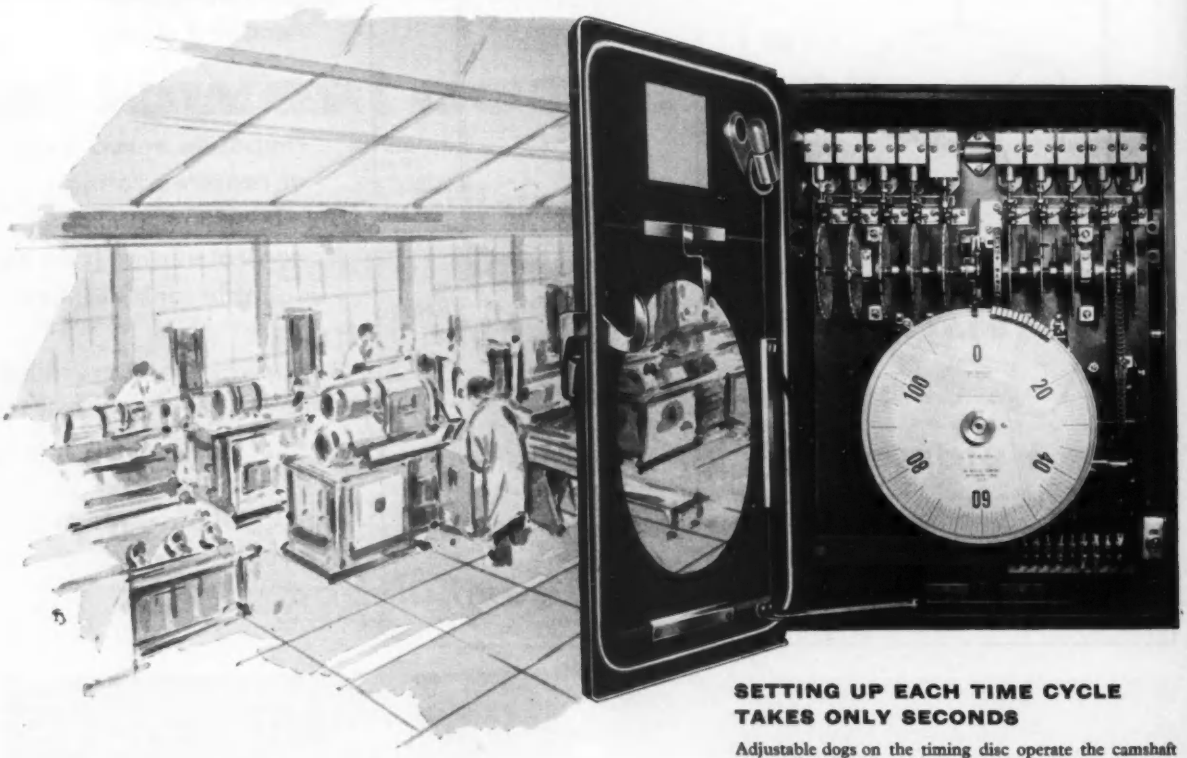
SE.7 RUGELEY · STAFFORDSHIRE · ENGLAND

Manufacturers of the world's widest range of industrial electronic control equipment

Higher production with lower costs

. . . and no rejects

NEW BRISTOL'S CIC 500 means *simplified process* time-cycle control



SETTING UP EACH TIME CYCLE TAKES ONLY SECONDS

Adjustable dogs on the timing disc operate the camshaft motor. Equally adjustable timing cams give exact sequential control of up to 10 process variables through either pneumatic pilot valves or electric pilot switches. Each switch or valve can be operated up to 24 times in a complete time-cycle. Timing discs available for a wide range of cycle times. Write for detailed, illustrated literature.

Any process that depends on the timing of a number of operations can be put under *exact* control with the CIC 500.

The operating principle has already been proved in Bristol's well-known earlier models — but this entirely *new* instrument embodies design refinements that make it *more accurate, more flexible, simpler to use and adjust*. For reduced operating costs and eliminating of rejects, learn more about accurate time-cycle control with the new Bristol CIC 500.

Rubber and Plastics Section — Process Control Division

ELLIOTT BROTHERS (LONDON) LTD

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I NSTRUMENTATION

E LECTRONICS

A UTOMATION

A COMPLETE INSTRUMENTATION SERVICE

With Evershed equipment you can meet all your process control requirements because there is an Evershed instrument for every purpose. Our Technical Advisory Service is freely available to discuss your particular problems in 'Supervisory Control.'

EVERSHED

VISIT STAND K 458 AT THE I.E.A. EXHIBITION

RECORDER CONTROLLER

A servo operated recorder to provide a permanent record of the measured value, has been added to the already comprehensive specification of the Evershed Mark 4 Controller which has found wide application throughout the world in all types of industries. Ingenious design allows a full 4″ chart display without increase of the panel cut-out which remains at the international standard of 144 × 144 mm.

The new controller, in two units, is completely self-contained, and embodies many proven features, *e.g.*, exchangeable printed circuit boards, built-in test and calibration facilities, bumpless transfer, etc.

EVERSHED SUPERVISORY CONTROL

'Transmission of 40 measurements over one pair of transmission lines, with simultaneous control signals (and positive confirmation) in the reverse direction over the same pair of lines'—this is the significant feature of this continuously cycling system. Added to this are: automatic monitoring of the system's correct operation, and automatic visual and audible alarms for dangerous conditions, etc.

Alternative facilities (for which the scanning cycle is rendered inoperative) are: 1. Selection "on-demand" of any of the measuring control points, or 2. Automatic initiation of the scanning cycle through changed conditions at a control point.

ANALOGUE TO DIGITAL CONVERTER

This new converter enables analogue measurement signals of Evershed Process Control Equipment to be presented in digital form! The instrument is designed to work under industrial conditions and is fast enough to meet all industrial measurement requirements. The output circuit can operate series or parallel displays, and/or print outs etc. It is essentially a simple device which keeps routine maintenance and service requirements at a minimum.

SOLIDS LEVEL TRANSMITTER

Evershed's comprehensive range of measurement transducers is further enlarged by this instrument which is designed to sense the level of granular solids in storage. Its output signal is suitable for application to a Process Controller, or for remote indication and/or recording.

A special feature prevents submergence of the sensing device by hopper discharged materials.

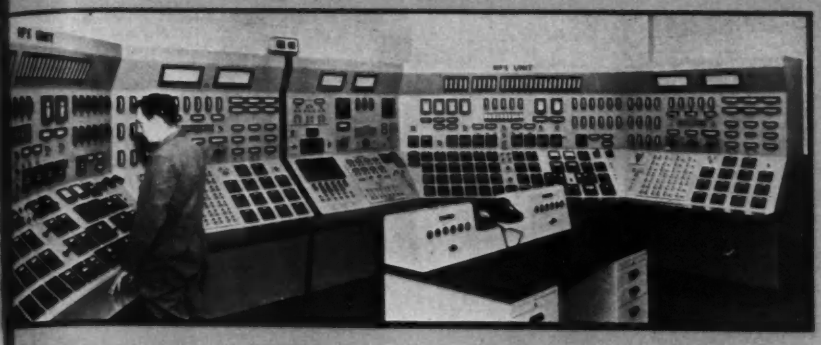
TEMPERATURE MEASUREMENT

This transmitting resistance thermometer is a fully transistorised, highly accurate instrument generating an output signal suitable for operation with Evershed Process Control equipment. It requires a minimum of attention over extended periods, permits easy matching to existing transmission lines, embodies built in test facilities, and calibration check facilities which do not need skilled personnel.

ALL-ELECTRIC VALVE POSITIONER

An all-electric Positioner, which operates in conjunction with a specially designed transistorised control/feedback amplifier, is now added to the range of Evershed Electro-pneumatic and Electro-hydraulic Positioners. The all-electric Positioner provides a 500 lb. thrust with an adjustable stroke of up to 2″, and is capable of a response time of 6 seconds per inch.

Exceptionally modest power consumption and practically no routine maintenance requirements (lubrication four times per year is adequate) combine to make this advanced Positioner particularly attractive. Even under most severe operating conditions it will maintain a sensitivity of 1%.



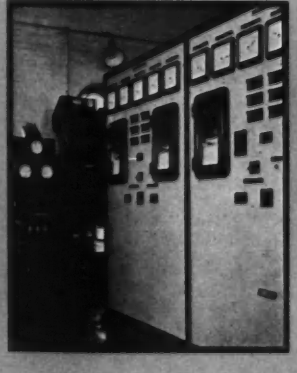
Boiler control panel at Little Barford Power Station—the first in Great Britain to be electronically controlled.

Part of Wissington sugar refinery control panel showing Evershed miniature recorders and process controllers.

Movement and levels of crude oil are controlled from this panel in a Kuwait Oil Company tank farm.

The supervisory panel at the Jersey Sewerage Board's installation at Bellozane. Measurements from six out-stations are sequentially sampled and continuously displayed. Remote control is also provided.

Colchester Water Works uses Evershed multipoint telemetering equipment for control, indication and recording at this main station and two remote stations.



EVERSHED

FLOW OR DIFFERENTIAL PRESSURE TRANSMITTER — TYPE ER 125

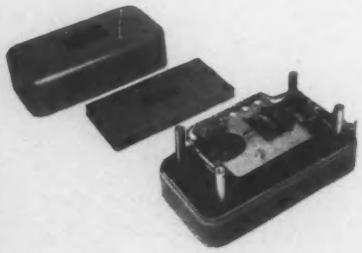
Designed for the control and remote indication of differential pressures up to 200 in. W.G. and at static pressures up to 1,000 p.s.i. Suitable for application to processes involving oil, viscous or corrosive fluids as well as water, steam or gases.

For further information ask for leaflet S.S.1.

GAS PRESSURE OR DIFFERENTIAL PRESSURE TRANSMITTER — TYPE ER 83

This transmitter embodies a limp diaphragm, and is capable of accurately measuring extremely low gas pressures. To provide local indications, a milliameter is included in the transmitter housing.

For further information ask for leaflet S.S.3.



SIMPLE COMPUTER — TYPE ER 92

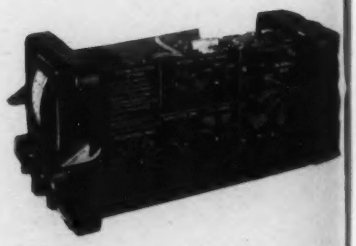
This instrument is used to evaluate continuously the variables and constants of a controlled process. The operations performed are: Addition; subtraction; multiplication of two variables or of a variable by a constant; division of two variables, or of a variable by a constant and *vice-versa*; squaring; square root extraction.

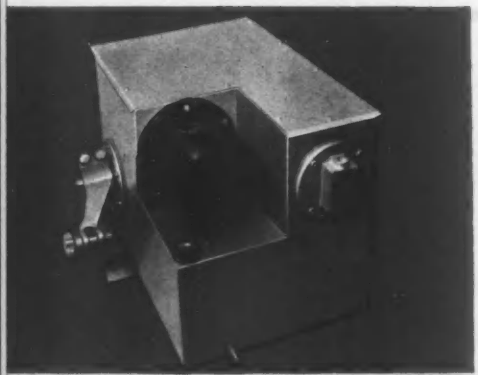
For further information ask for leaflet S.S.10.

ELECTRONIC PROCESS CONTROLLER MARK IV

The Evershed 3-term Process Controller operates in conjunction with Evershed Electronic Repeater Transmitters which provide the measured value signal, and when compared with a manually adjustable 'desired value' current, develops a controller output signal which contains 3-term circuitry (*i.e.*, proportional, integral and derivative) components.

The output signal may be used to operate Evershed electro-pneumatic, electro-hydraulic or electro-mechanical positioners, valves, dampers, etc., in order to maintain the process under control in the desired manner. For further information ask for leaflet S.S.12.





STANDARD ELECTRO-HYDRAULIC VALVE POSITIONER

Of robust construction, this equipment which incorporates the hydraulic jet pipe relay principle, can be used to operate the heaviest dampers or valves. It is completely self-contained with its own motor driven pump, and accurately positions the damper or valve according to the value of the signal received from the control system, irrespective of the magnitude of forces to be overcome.

For further information ask for Publication No. 520.

INSTRUMENTATION & CONTROLS DIVISION

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ACTON LANE WORKS · CHISWICK · LONDON W.4

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Publication No.

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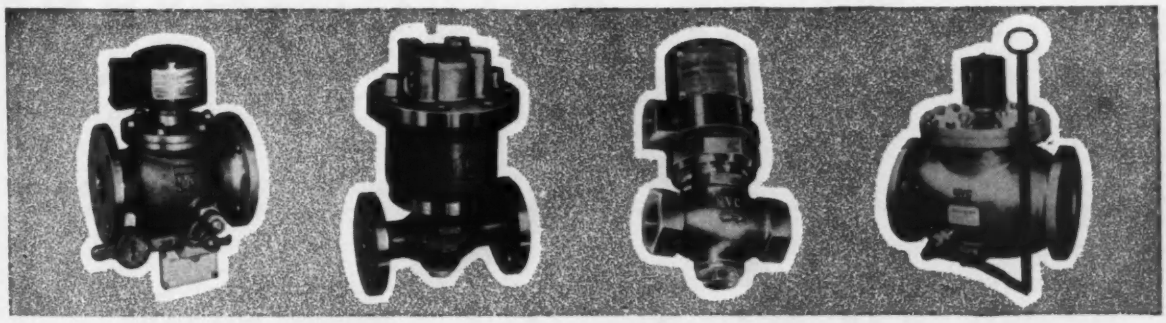
(Because we like to see our customers satisfied!)

Special and individual requirements are our particular speciality. And we go to great lengths (including bending over backwards) to see a job well done—
and to see that our customers are happy!
Over 30 years' experience and 'know-how' has been built-in to our range of over 100 automatic control valves. People control water with them, gas with them, oil with them, steam with them and a host of other industrial liquids and gases too! Mushrooms are grown with them, jam is made with them and ships cargoes are frozen with them!
You'll find that expert consultation and advice cost you absolutely nothing at MVC. Our full experience is at your disposal. Many times, what has first appeared to be impossible has been achieved! Why not write *now* for our new comprehensive catalogue No. 31 which contains full details of our complete range!



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The Magnetic Valve Company Ltd

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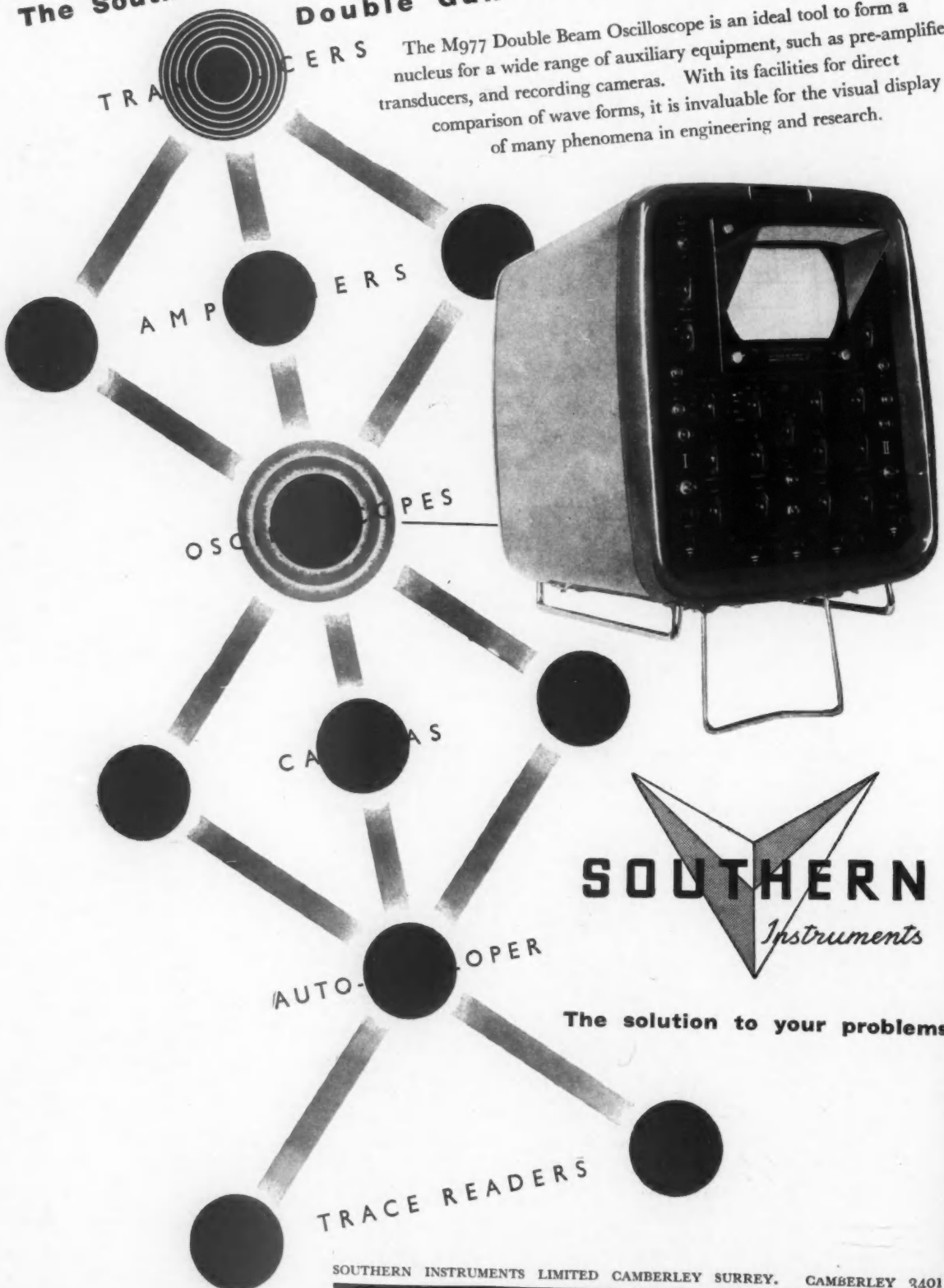
The Southern Instruments system

Double Gun Oscilloscope

The M977 Double Beam Oscilloscope is an ideal tool to form a nucleus for a wide range of auxiliary equipment, such as pre-amplifiers, transducers, and recording cameras. With its facilities for direct comparison of wave forms, it is invaluable for the visual display of many phenomena in engineering and research.



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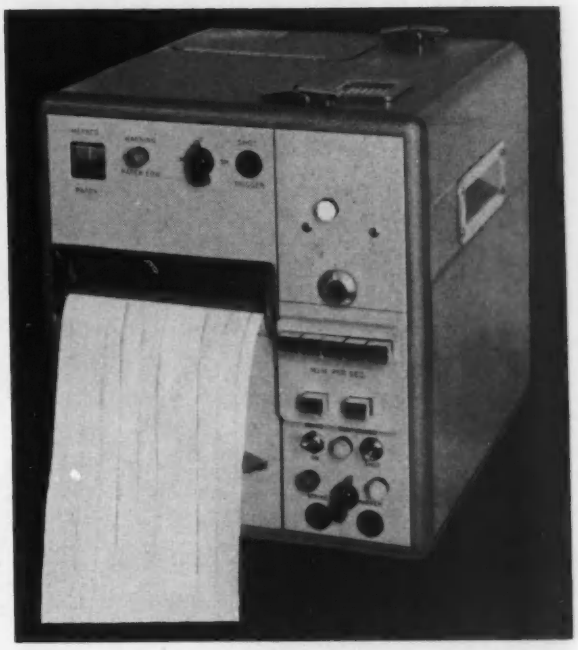
The solution to your problems

SOUTHERN INSTRUMENTS LIMITED CAMBERLEY SURREY. CAMBERLEY 3401

S.E.L. makes news

S.E.L. Direct-writing U.V. Galvanometer Recorders



- **Up to 50 channels simultaneously**
- **Up to 12″ chart width**
- **0·05 to 80 ins/sec in fifteen steps**
- **Galvanometers from 0–100 to 0–5,000 c/s**
- **Electronic Flash Timer**

S.E. Laboratories Ltd announce a new range of Direct-writing U.V. Galvanometer Recorders offering outstanding accuracy, versatile range, simplicity and long life in use. Models are available with chart widths up to 12″, recording up to 50 channels simultaneously. A range of ultra-sensitive galvanometers covers frequencies from 0–100 to 0–5,000 c/s. The low-frequency ranges are suitable for direct connection to thermo-couples, strain gauge transducers and other low-voltage or low-current signals without any intermediate amplifiers. There is a choice of speeds from 0.05 to 80 ins/sec in fifteen steps. One of the special features of these new S.E.L. recorders is the instant striking of the U.V. lamp, and rapid replacement from the front in case of failure. S.E.L. would like to send you full details of this new development.

S.E.Laboratories Ltd

North Feltham Trading Estate, Feltham, Middlesex. *Telephone Feltham 5876*

I.E.A. EXHIBITION Stand No. D.167

Tick **No 40** on reply card for further details

TELESIG Screw Pumps are positive displacement pumps. Simply constructed, they offer exceptional performance and long life. TELESIG pumps effect delivery by means of three parallel screws engaging each other, the power-driven central screw driving the two side screws. They may be run at high speed thereby reducing motor sizes and installation costs.

TELESIG Screw Pumps offer the following advantages:

- Self priming.
- Delivery free from pressure pulsation.
- High working speed — small size.
- Near-silent operation.
- Simple construction.
- Minimum maintenance and easy replacement of working parts.
- Long life.

TELESIG Screw Pumps are made in three basic ranges: for low pressures up to 300 psi, for medium pressure up to 1000 psi and for high pressures up to 2,500 psi. 42 sizes are available covering a wide range of capacities.

TELESIG

Screw Pumps by Telehoist

TELESIG pumps and equipment are made by Telehoist under licence from the Swiss Industrial Company (SIG).

Telehoist Limited. Cheltenham England. Telephone: Cheltenham 53254

an associate company of Wilmot Breeden Ltd.

S.E.L. makes news

S.E.L. Frequency D.C. Converters

Two new transistorised Frequency DC Converters with remarkable specifications:

Frequency ranges: 10-200, 10-1,000 and 10-5,000 c/s for full-scale output.
Accuracy: 0.75% including meter, 0.25% with precision indicator.
Input signal range: 10 mV to 10 V r.m.s.
Power supply: Internal battery, or 200-250 volt A.C. mains.
Size: 10½ x 5½ x 6". Weight: 9 lbs.

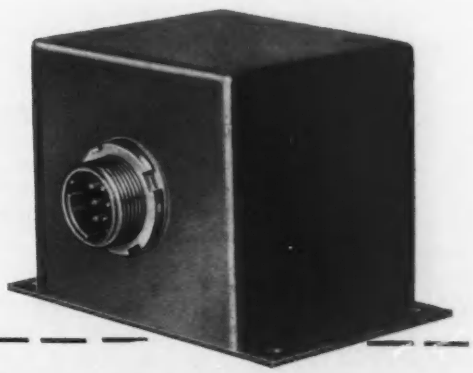
Type S.E. 700

Industrial and general-purpose instruments, chiefly for rate-of-flow indication, working with Meterflow impeller flowmeters. Also suitable as tachometers or rate meters with tranducers generating electrical pulses. Indication on 3½" cirscale meter or on external indicator, chart or galvanometer recorder. Check facility for calibration before use. Housed in practical metal case with drop-away lid and fixing handle for easy viewing.

Type S.E. 710

Mainly intended for aircraft or missile applications where electrical pulses have to be converted into voltage or current signals as inputs to telemetering transmitters, tape recorders, galvanometer recorders or indicators. Fully transistorised, exceedingly accurate and stable, robust, small and light.

Frequency range: 10-1,000 c/s.
Linearity: ± 0.2%.
Compensated Temperature Range: −20 to +100°C.
Output: 5 volt DC at 1,000 c/s ± 1%.
Input: 10 mV to 10 V r.m.s.
Size: 2¼" × 2¼" × 2¼". Weight: 18 ozs.



S.E.L. would like to send you full details about these new instruments

S.E.Laboratories Ltd

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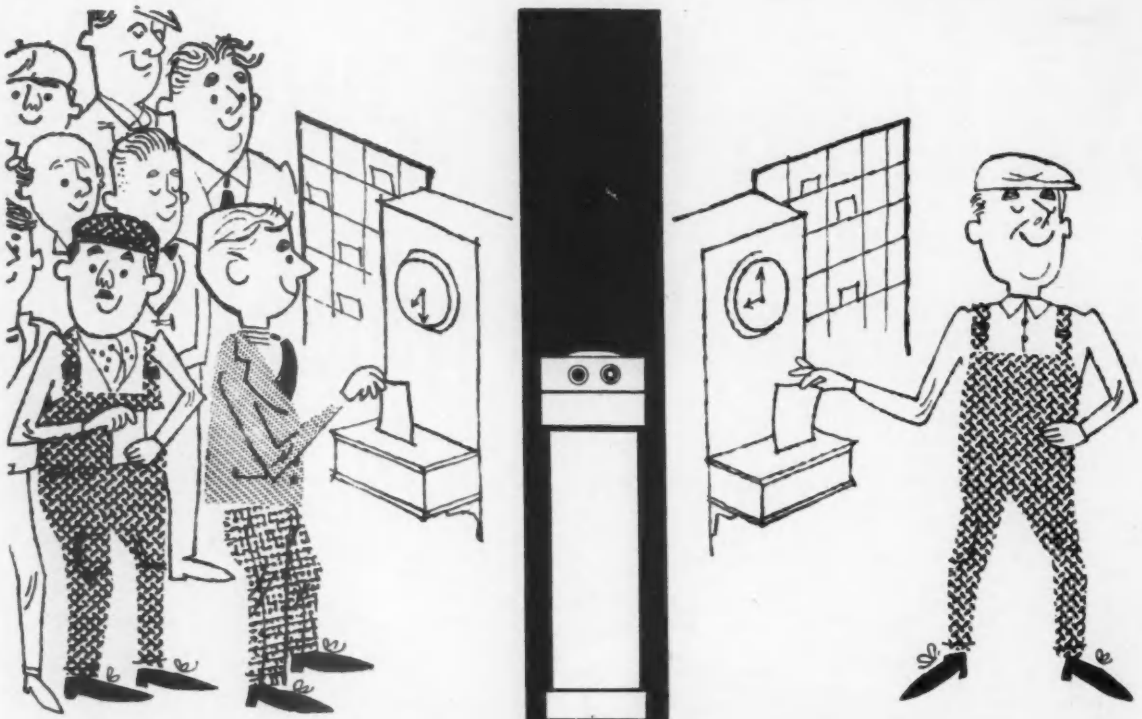

OUR MANPOWER SAVES YOURS!

In almost every industrial process there is some stage where manpower could be cut by the application of fluid power. It is here that our labour can prove so labour-saving, since the whole weight of the Baldwin Fluid Power Division is directed at cutting waste manpower and speeding production.

BALDWIN TECHNICAL REPRESENTATIVES cover the British Isles. They are experienced fluid power engineers, who will quickly show you how to harness waste or under-used power by fitting Baldwin equipment which, because of its unit construction, can be supplied from stock quickly.

Write now for the Fluid Power Catalogue C/503

THE EXPERT BALDWIN DESIGN STAFF at Dartford will plan automation schemes for any operation or series of operations up to the largest automatic production lines.

HIGHLY SKILLED MEN on the Baldwin shop floor devote their attention to producing the superb finish, reliability and precision that characterises Baldwin Fluid Power equipment. There is a standard range of 384 pneumatic and hydraulic cylinders and over 700 control valves.

We have long found that the best way to success is to give the best service. At every level, our manpower is aimed at increasing production for industry —and for Baldwin too, of course!

Fluid Power Division

Baldwin Industrial Controls

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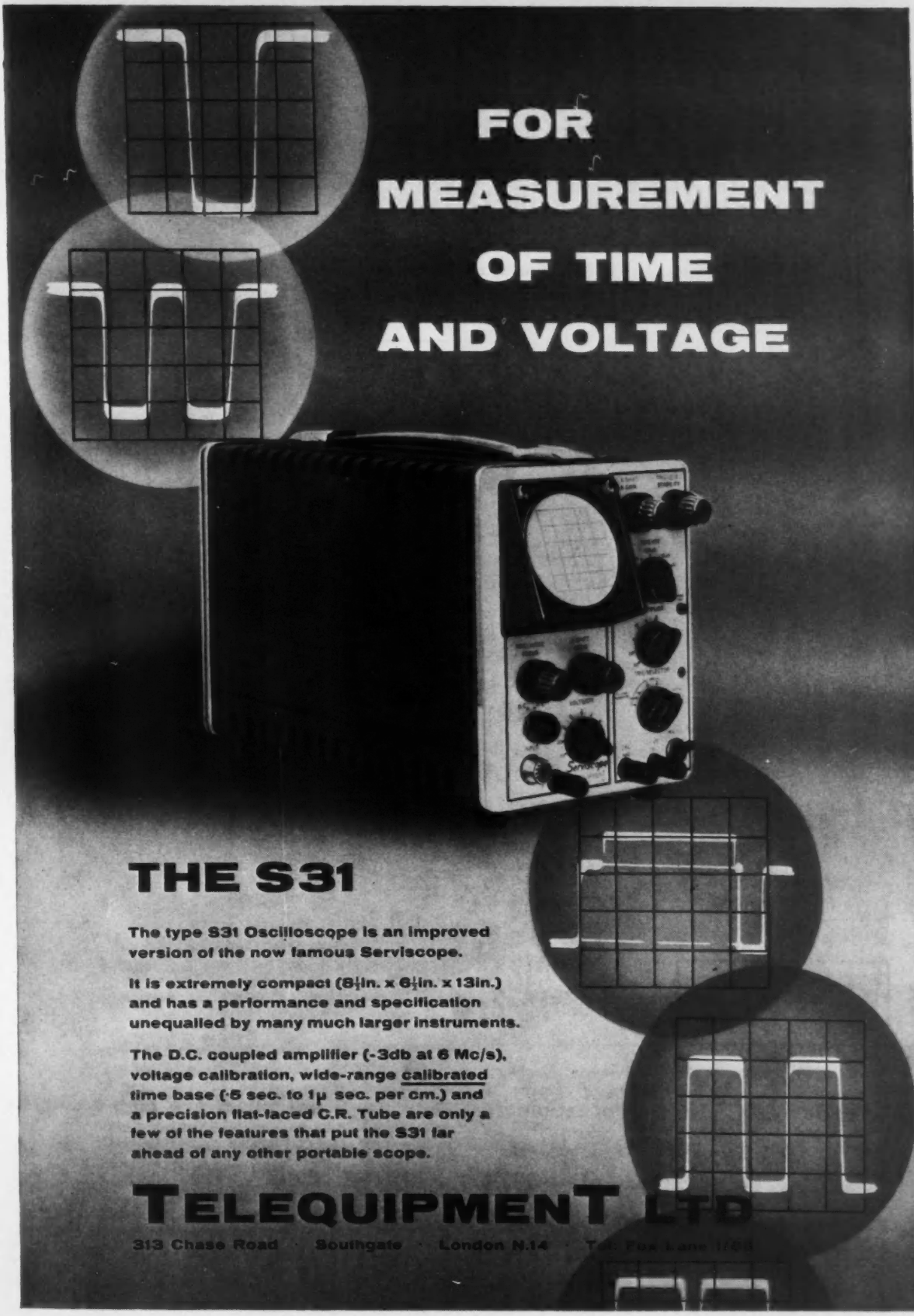
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MEASUREMENT
OF TIME
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THE S31
The type S31 Oscilloscope is an improved version of the now famous Serviscope.
It is extremely compact (8½in. x 6½in. x 13in.) and has a performance and specification unequalled by many much larger instruments.
The D.C. coupled amplifier (-3db at 6 Mc/s), voltage calibration, wide-range calibrated time base (·5 sec. to 1μ sec. per cm.) and a precision flat-faced C.R. Tube are only a few of the features that put the S31 far ahead of any other portable scope.
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THE PRICE OF THE S31 IS £75

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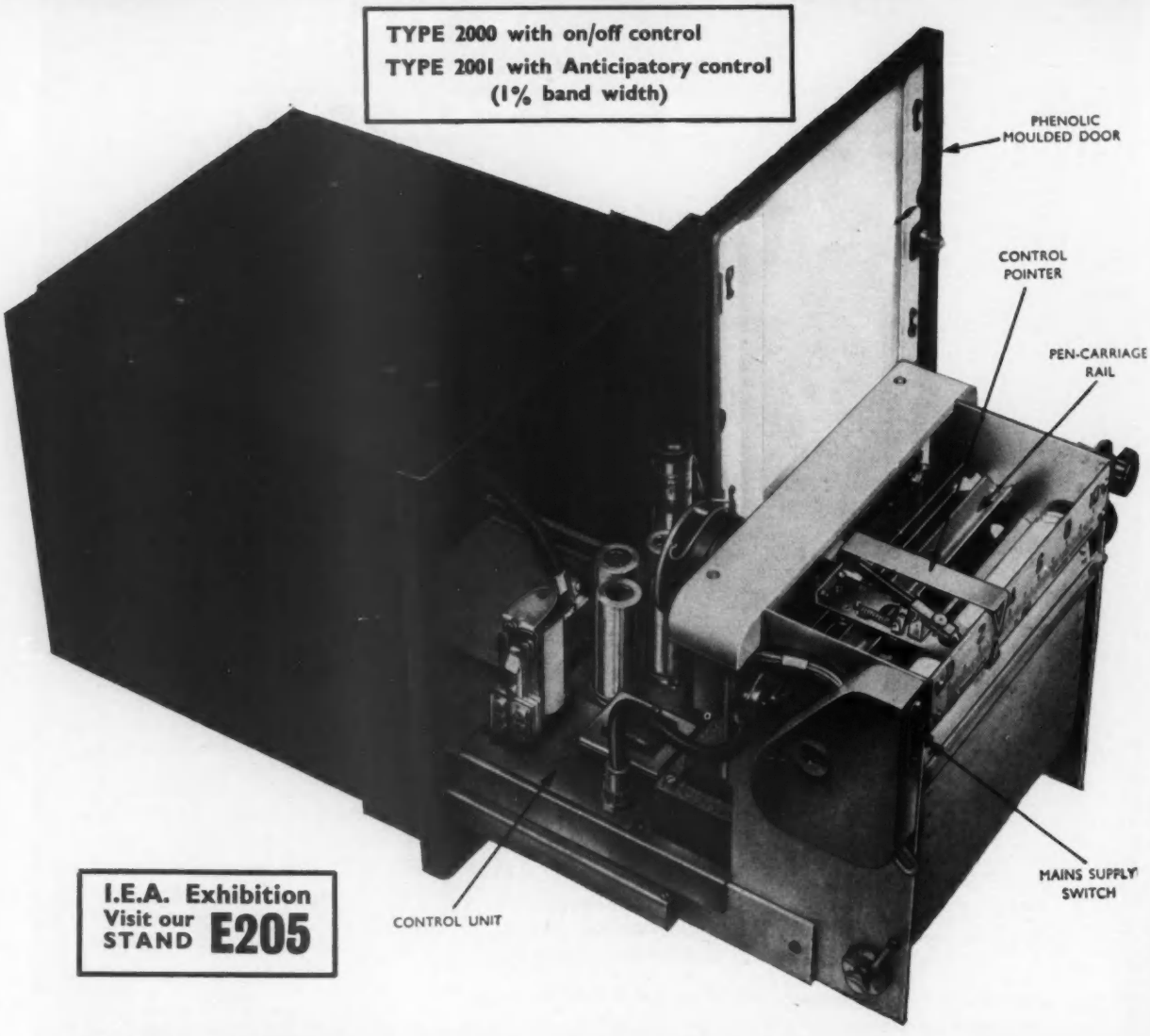
ETHER 'XACTROL'

LIMITED

Potentiometer Recording Controllers, SERIES 2000

TYPE 2000 with on/off control
TYPE 2001 with Anticipatory control (1% band width)



I.E.A. Exhibition
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ETHER 'XACTROL' Potentiometer Recording Controllers are high-quality instruments, of the very latest design, for accurately controlling and measuring temperatures of — 200°C up to + 2,000°C. They are equally suitable for measuring variables such as speed, strain, pressure and hydrogen-ion concentration, as well as any other quantity that can be expressed as an electrical signal.

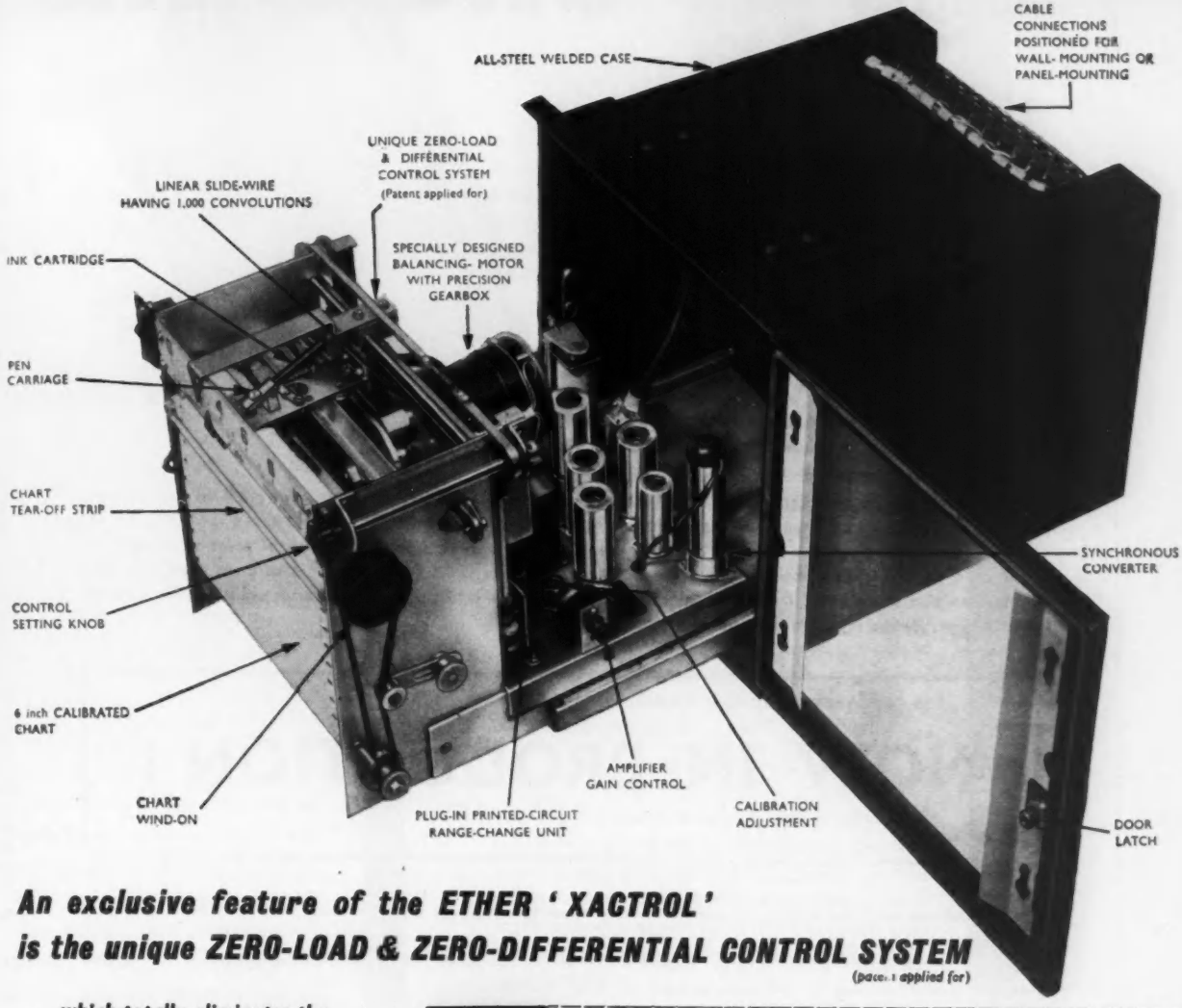
Tick No 45 on reply card for further details

* *SIMPLICITY OF DESIGN* * *EASIER RANGE CHANGING*

provide EVEN HIGHER STANDARDS OF PERFORMANCE

SALIENT FEATURES INCLUDE!

* Unique Zero-load & Zero-differential control system
* 6" calibrated scale * Small panel cut-out 10½" 9½"
* Patent Ink Cartridge * Front control-point setting



An exclusive feature of the ETHER 'XACTROL' is the unique ZERO-LOAD & ZERO-DIFFERENTIAL CONTROL SYSTEM
(Patent applied for)

—which totally eliminates the use of mechanically-operated linkages and snap-action switches

- **ZERO-LOAD even at control point**
- **ZERO-DIFFERENTIAL**
- **WIPING-ACTION, continuously-cleaning contacts**
- **ADJUSTABLE OVER FULL SPAN**

from £125-0-0 delivered

FILL IN AND POST NOW

Please supply, without obligation, full details of the ETHER 'XACTROL.' c.s

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*NGING * GREATER ACCESSIBILITY * EASIER SERVICING & INSPECTION*

ILLUMINATED QUADRANT CONTROLS

The new ELCOM quadrant instrument offers exciting possibilities to the designer of control desks and equipment.

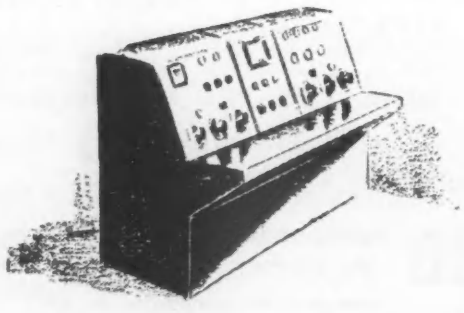
The instrument houses two individual channels operating separately or ganged and fits into a panel cut-out approximately 5" × 1$\frac{13}{32}$". Eight instruments mounted side by side take up panel space of only 5" × 5$\frac{1}{2}$".

The provision of illuminated scales is a feature offered only by the ELCOM quadrant control. Auxiliary switches incorporated in the instrument operate colour changes of this illumination at predetermined positions of the movement of the quadrant arm, thus providing cue lights or warning signals at the actual point of control. For instance, a scale may be illuminated by a green light changing to red when the channel becomes alive. This light change can also be operated from an outside source, e.g. to show when a channel becomes available. The auxiliary switches operate cue lights or signals at other locations.

NOW IN PRODUCTION !

The control can be fitted with a resistor network or supplied simply as a stud switch with a smooth or detent action.

A feature of the design is the 'plug in' facility which allows the whole instrument to be withdrawn or replaced instantly should cleaning or overhaul become necessary.



The ELCOM quadrant instrument has an application on every control desk or panel and full information will be given on request.

ELECTRONIC COMPONENTS

WEEDON ROAD INDUSTRIAL ESTATE
NORTHAMPTON

Telephone: Northampton 2467 & 1873
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all in one

Consistent accuracy, small size, mechanical ruggedness and an efficiency unimpaired by extreme conditions—all these, in every synchro made by Ketay.

✳ As a result of recent design developments, the latest Ketay synchros are able to detect shaft movement of as little as three minutes, or 1/7,200 of a revolution! In achieving this standard of accuracy—and an unfailing reliability—an important part is played by the through-bore construction which is a vital characteristic of these synchros.

✳ They are small and light enough for use in many critical applications where size and weight must be minimal. The smallest in the current range—which covers sizes 11 to 23, with size 08 soon to be in production—has an outside diameter of just 1.1″ and weighs only 4.0 ounces.

✳ This valuable miniaturisation involves no sacrifice of mechanical ruggedness—with stainless steel housing and encapsulated windings, Ketay synchros will perform efficiently and consistently under most severe conditions of impact or vibration.

✳ They also maintain the same high level of performance in extreme temperatures. Generally, the operating range is −55°C to +85°C, but recent progress has enabled even these figures to be bettered; a new Ketay series of synchros capable of working at 125°C is already available and developments are in hand to improve this figure to 200°C.

✳ Ketay synchros have an outstandingly high resistance to moisture and other climatic conditions; this is afforded by stainless steel housings, shafts and bearings, hermetically sealed windings and other design features.

Every one of these units embodies the highly specialised knowledge of Ketay engineers who are continually at work on environmental and accuracy problems connected with servo components and systems. Their very considerable experience and skills, backed by superior development facilities, are available as a service of which all plant designers and engineers are invited to make full use.

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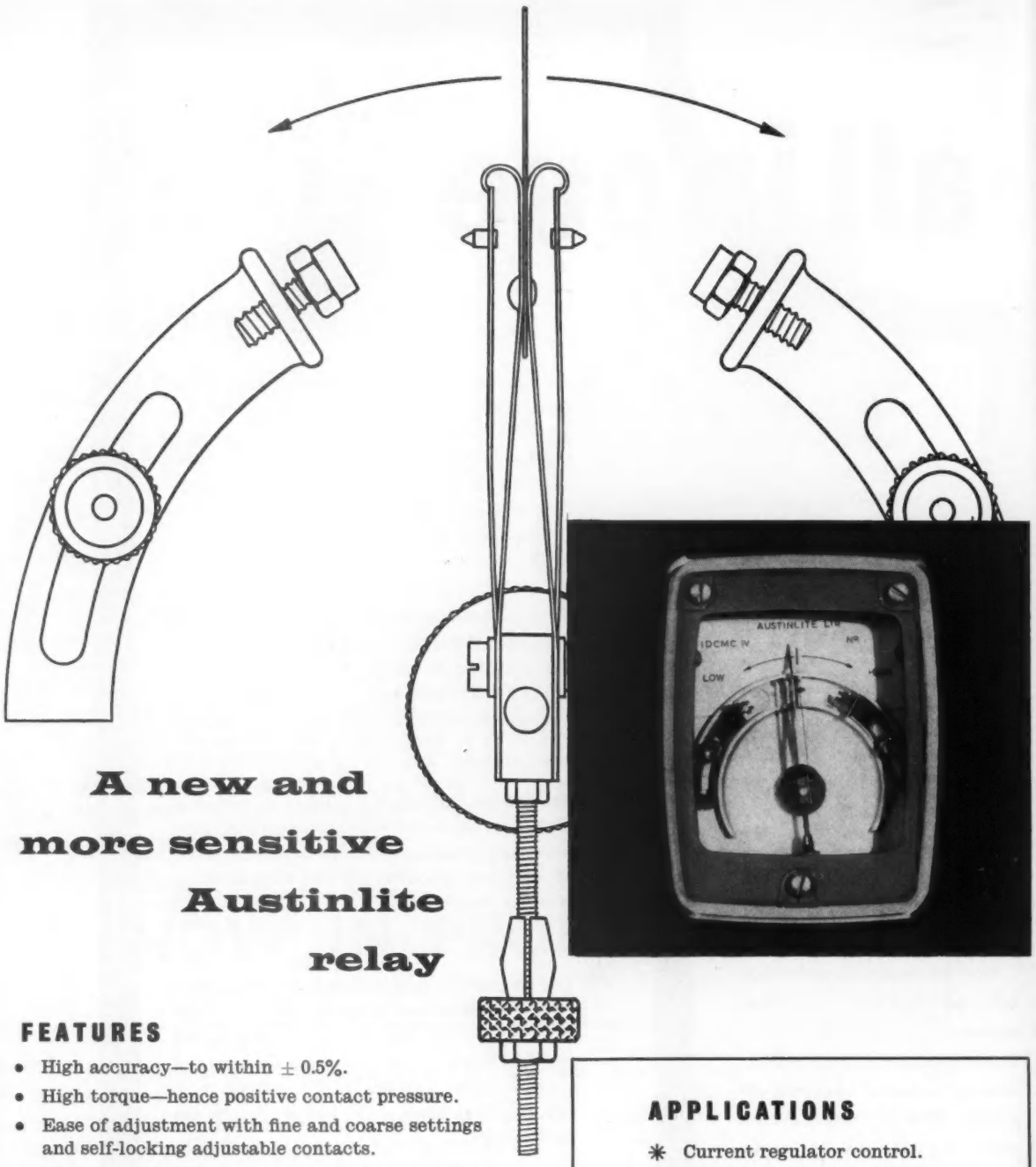
K9



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FEATURES

- High accuracy—to within ± 0.5%.
- High torque—hence positive contact pressure.
- Ease of adjustment with fine and coarse settings and self-locking adjustable contacts.
- Choice of either two or four adjustable contacts.
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- Conforms to Post Office Specification P.T. 1025B.
- Suitable for current or voltage sensing on either D.C. or A.C.

APPLICATIONS

- ✳ Current regulator control.
- ✳ Voltage regulator control.
- ✳ Monitoring duties.
- ✳ Limiting duties.
- ✳ Equipment protection.

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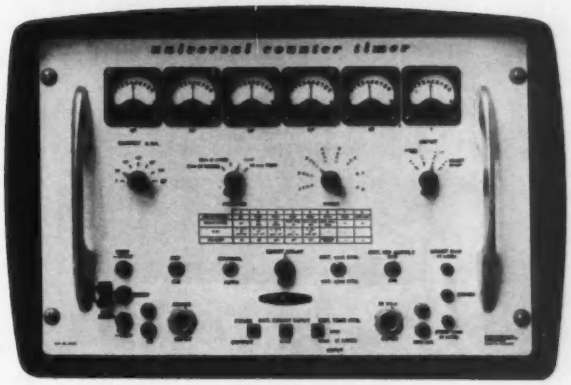
Transistorized UNIVERSAL COUNTER TIMER



Frequency Measurement

Random Counting

Frequency Division

Time Measurement

Frequency Standard

This fully transistorized portable equipment provides for a wide range of time and frequency measurement as well as facilities for counting, frequency division and the provision of standard frequencies. The facilities available are briefly listed below:

TIME/UNIT EVENT (1 LINE): For the measurement of the time interval between two occurrences in a continuously varying electrical function in the range 3μsec to 1sec. The time for 1, 10 or 100 such events can be measured.

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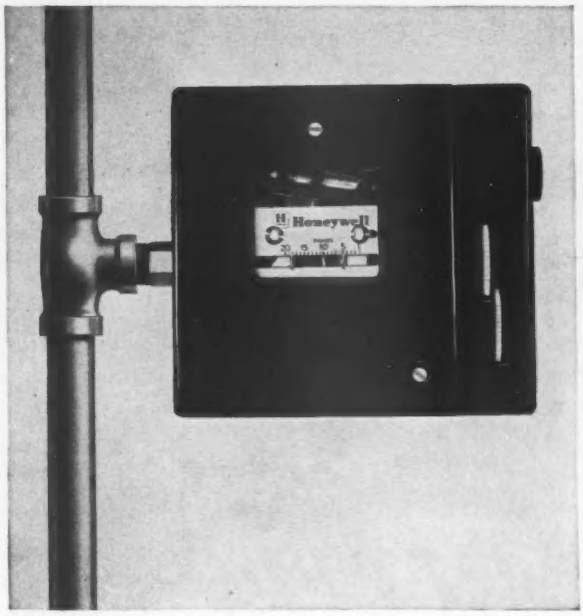
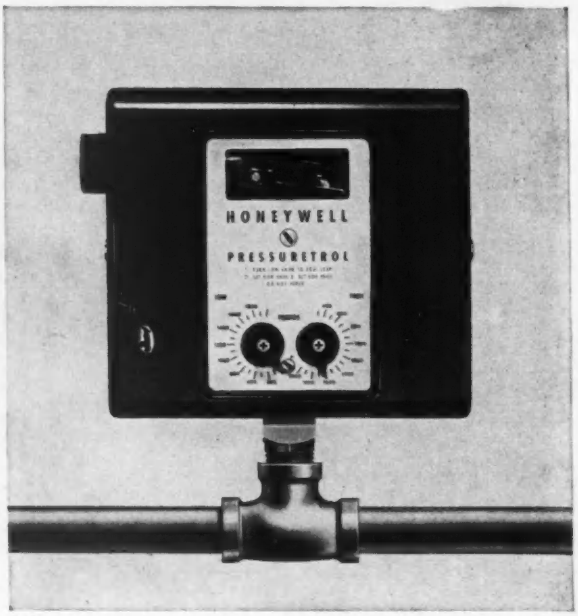


P444



P428

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P428 Flush Mounted

The new P444 Pressuretrol is a low-cost device for industrial application up to 150 p.s.i. The rugged P428 Pressuretrol is also designed specifically for industrial use. Use it for gas or liquids at pressures to 5000 p.s.i. Use either of them as controllers or as high or low limit devices. Their outstanding features are:

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* **Visible switch position** — Window in front of case reveals at a glance whether mercury switch is made or broken. Changeover versions available.
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* **P444** is diaphragm operated, using similar materials.
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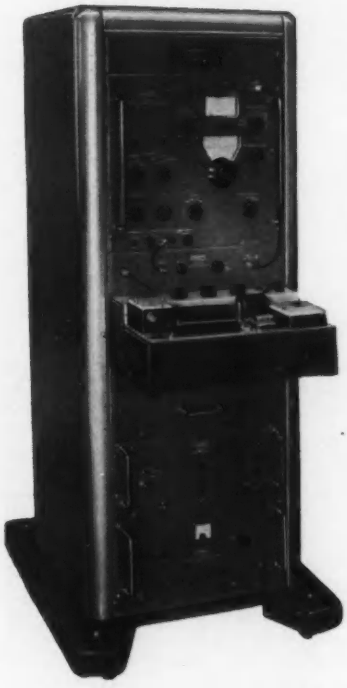

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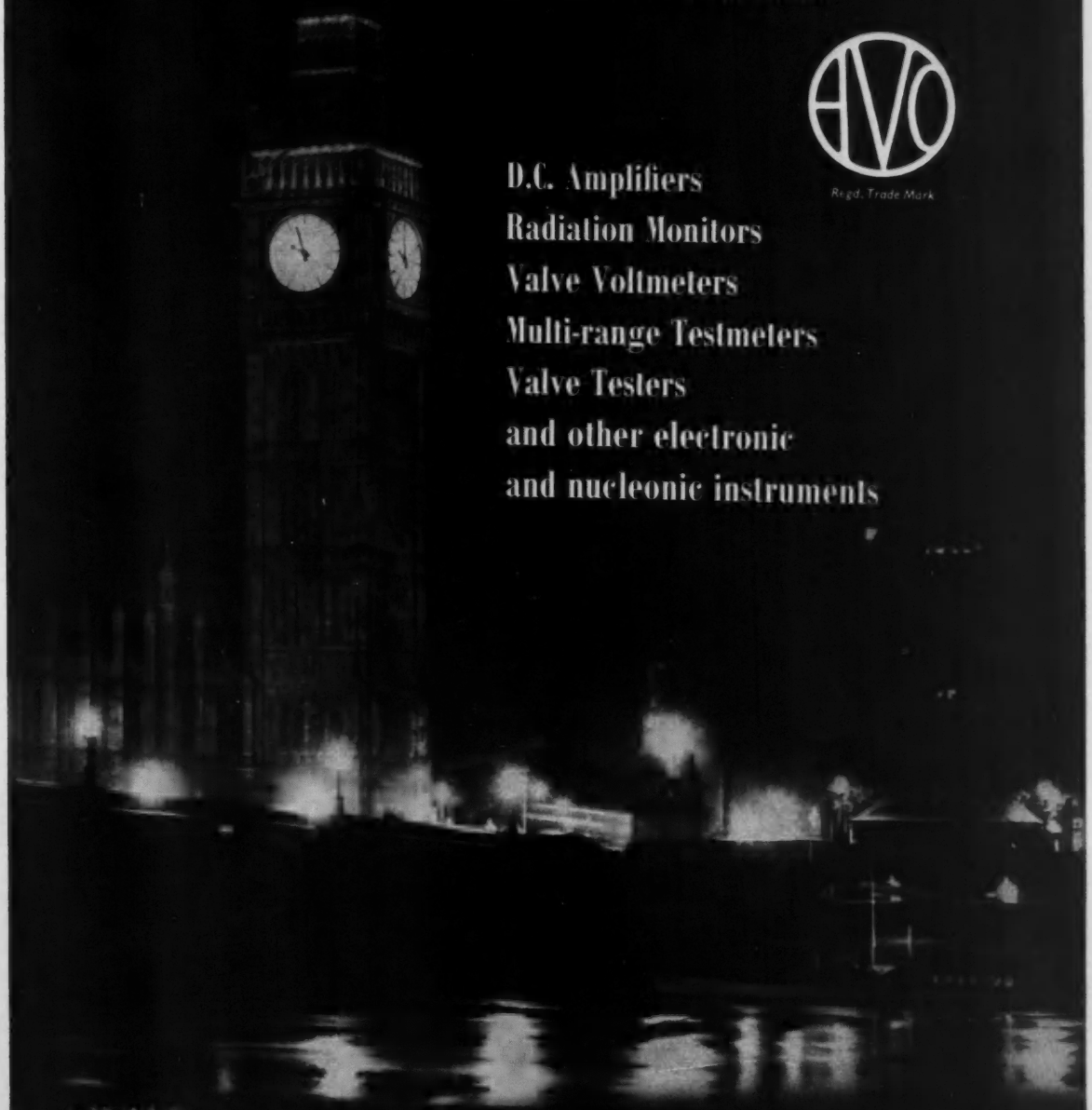

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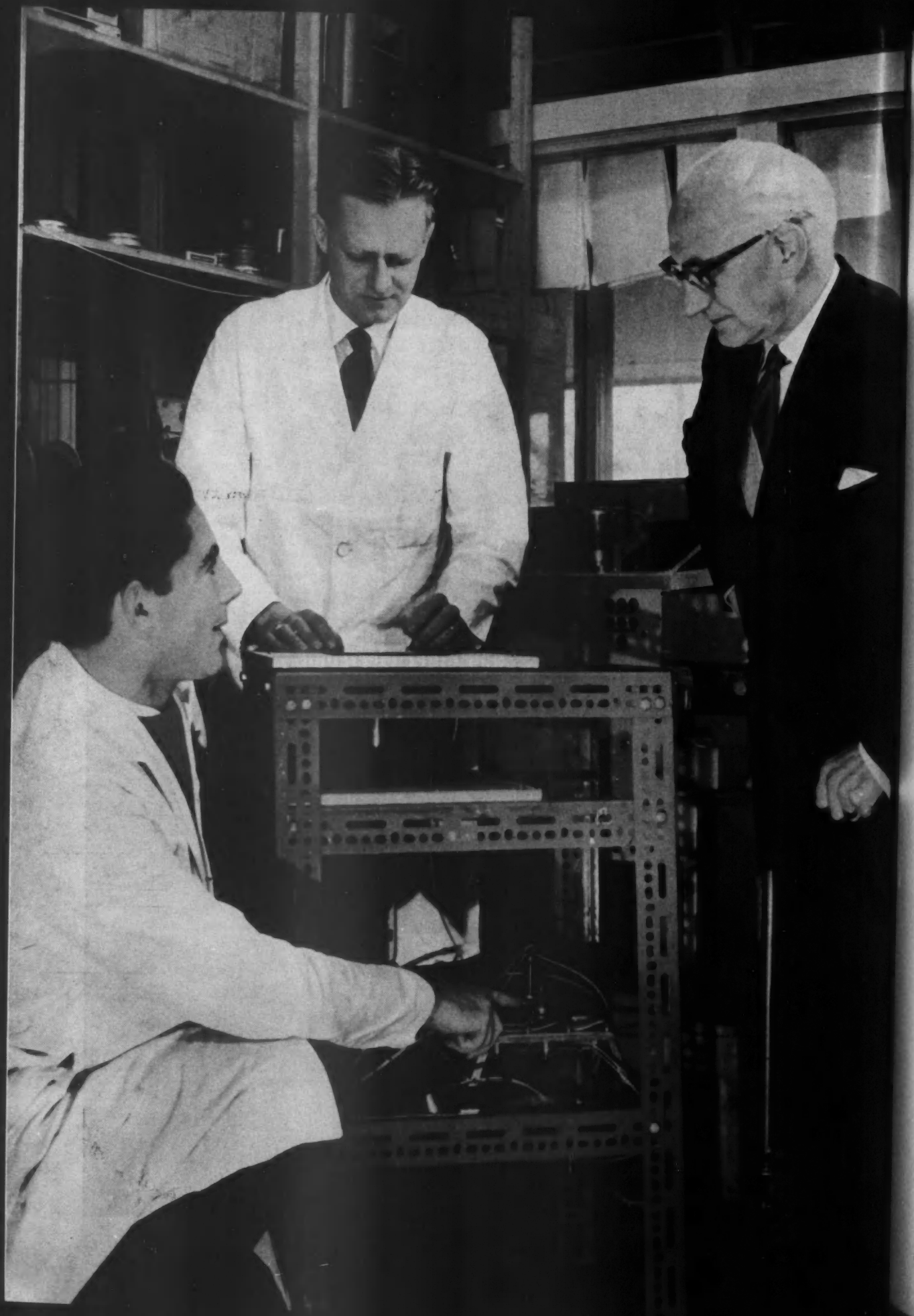

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Which little boy will become an Electrical Design Engineer?

The six little girls in the foreground immersed in the closed shop of their femininity are, like the front row of any chorus, really there for effect; more likely to distract than inform. And dark-haired Christopher immediately behind them, striding with such confidence is not the one we seek. In any case three steps later he will trip and fall prone and the little girls' smiles will change to immoderate laughter.

Richard the fair-haired boy on his knees (extreme right) would, at first sight, seem a likely choice but he shines at handicrafts rather than arithmetic (and prefers football to either). No, the boy who will become the electrical design engineer is the one uncovering a mysterious article from the sand. He is exploratory by nature, able to grasp abstracts with the same interest he now shows. Eventually (although they do not know each other yet) he will marry the little girl who is walking out of the extreme top right-hand corner. To her B. & R. Relays will mean nothing whatsoever; to him quite a lot.

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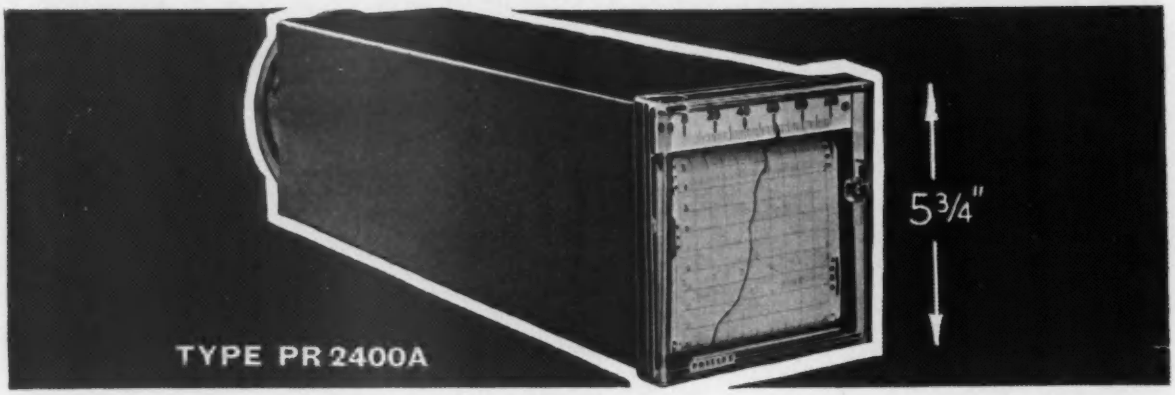

FEATURES Small panel space of 144 x 144 mm (approx. 5¾" x 5¾") · Reliable null-balancing potentiometer system · Easily interchangeable ranges · Transistorized plug-in amplifier with printed wiring · Unique chart-winding system · High indicating speed and critical damping · Scale calibration for mV or all conventional thermocouples · Completely mains operated.

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CHART-SPEED With built-in gear box 3 different speeds can be selected: 10, 20 and 60 mm/h. Can be supplied with electro-mechanical clutch so that by means of external switch, chart movement can be accelerated by a factor of 60.

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ACCURACY 0·5%; the accuracy can be maintained after exchange of range box.
REPRODUCIBILITY 0·2% of span · SCALE LENGTH 100 mm.
STABILITY 10% mains variations have an influence of less than 0·1%
BALANCING SPEED Less than 1 sec. for full scale deflection; damping critically adjustable.

RECORDING With flexible capillary stylus supplied from sealed ink container mounted under measuring carriage. Line thickness approx. 0·3 mm.

CONSTRUCTION Sheet-metal case in grey hammertone with all plastic door. Front dimensions 144 x 144 mm; depth 510 mm; panel opening 138 x 138 mm. (5¾" x 5¾"—20"—5½" x 5½").

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This photograph shows the lighter weight and compact size of the plug-in transistorized amplifier.

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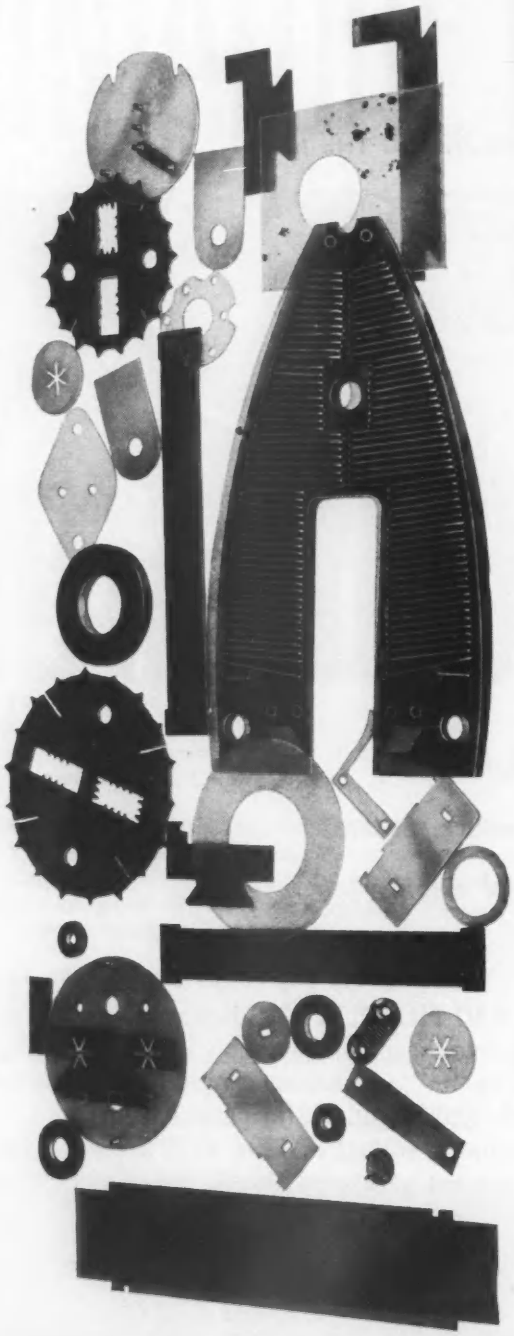

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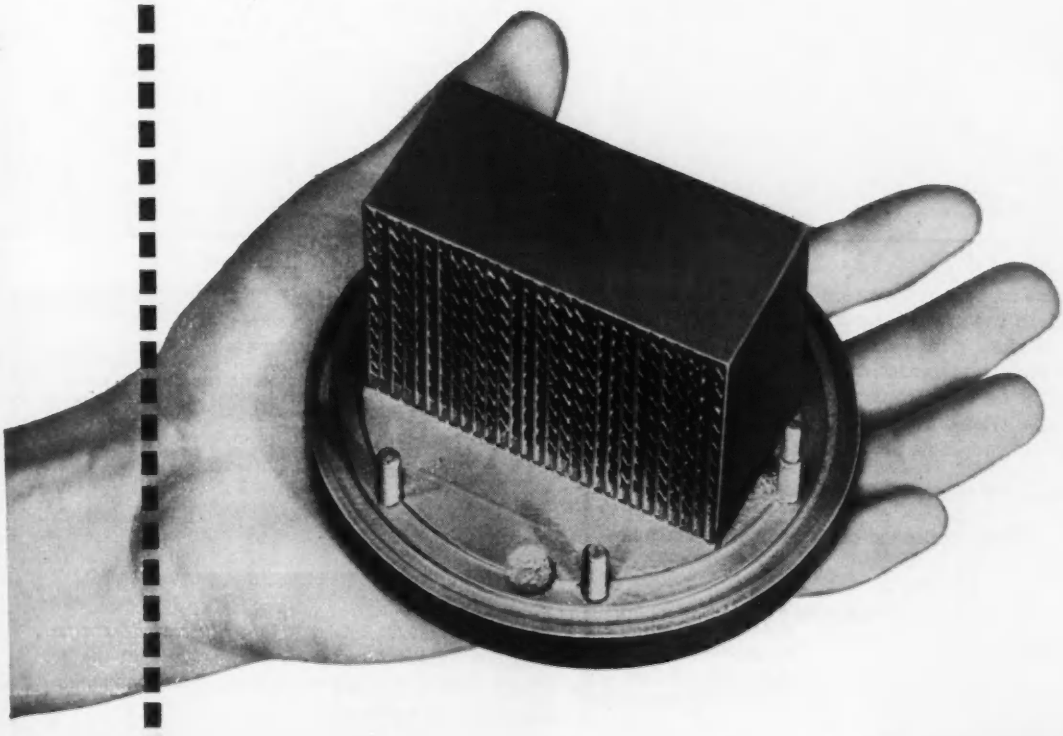

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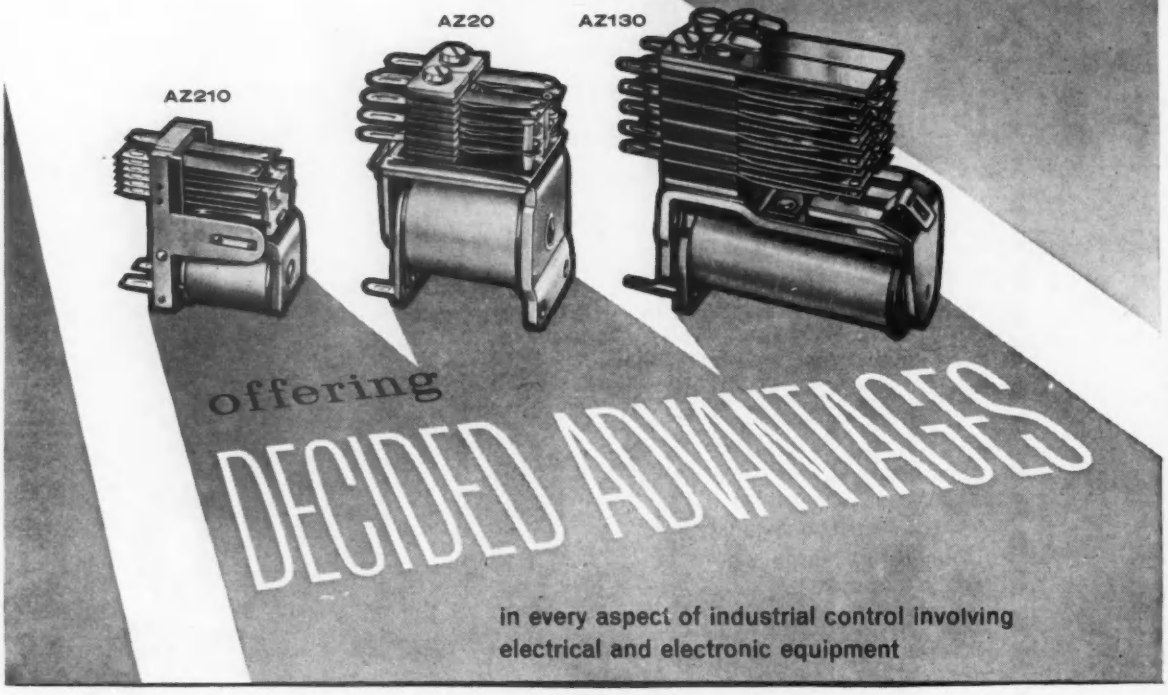

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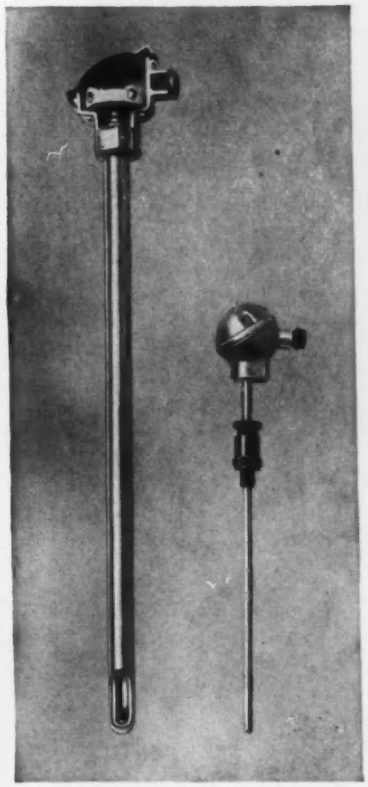

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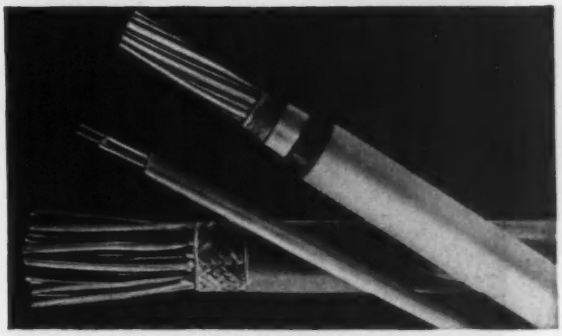

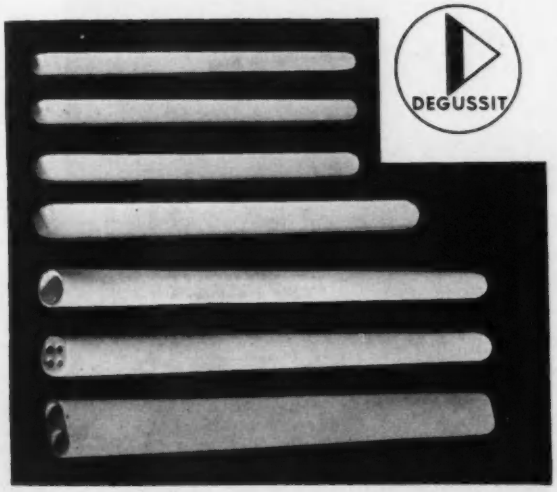

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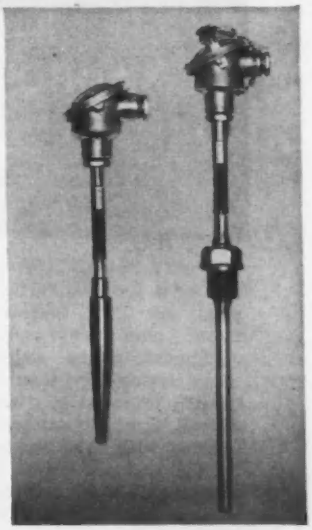

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The new Addo-X 347E (S) digital printer is specially designed to print out from digital volt meters, ohm meters and other equipment giving automatic range setting—and thus requiring the print-out of *a variable decimal point*. It can also be supplied with half the capacity decimal and half special, to enable a small calculating register to be used.

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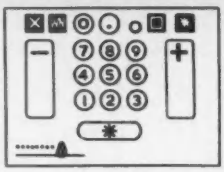

For full details, or specialist advice and consultation, please write to: Bulmers(Calculators)Ltd., ADDO-X Automatic Data Processing Division, Empire House, St. Martins-le-Grand, London EC1. MONarch 7991.

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of that of the famous Flexipush Indicating Controller—yet its performance, durability, accuracy and sensitivity is in every way equal to the well-known qualities of the Flexipush.

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(WELL IF THAT DOESN'T DO THE TRICK AND GET THEM SENDING IN FOR OUR LITERATURE ABOUT ALL THAT INDUSTRIAL CONTROL EQUIPMENT...)

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Overleaf we show, in easy reference form, the stimulus which Solartron is giving to every field of human endeavour today. This can only be a brief outline—but the responsible businessman owes it to himself to be well-informed on the exciting potential of electronics, the accelerator of progress. Each step forward in electronic technique or application sparks off a chain reaction of inventiveness and progress in every industry.

SOLARTRON

Learn here how Solartron is accelerating progress, cutting costs and solving problems in your field!

	INSTRUMENTS	COMPUTERS
	A complete range of precision measuring instruments, oscilloscopes for every application; dynamic analysis equipment; digital display instruments and both conventional and transistorised power supplies.	*Advanced modular construction 'Space' series computers ranging from the 'S'—amplifier Analogue Tutor, through 'Minispace' and 'Space 30' to 'Space 60', '90'—etc. larger special-purpose machines.*
COMMUNICATIONS	**Telecommunications** **Radio** **Television** **Facsimile** **Teleprinting** **Radar & Sonar**	Line and radio link power measurement; a.f., and r.f. amplifier testing; precise calibration; vectorial measurement and oscillographic, metered or digital display; microwave test and power supply instrumentation.	Synthesis and evaluation of networks; repetitive test of simulated systems under programmed conditions; design evaluation of overhead transmission equipment; solution of dynamic traffic loading problems.
AUTOMOTIVE & TRANSPORT	**Aviation** **Railways** **Shipping** **Roads** **Spacecraft**	Vibration analysis and display; evaluation of aircraft and automotive servo systems; testing of mobile electronic equipment; design and development of power controls, instrumentation of research vehicles and guided weapons.	Servo system, suspension and power transfer system simulation and evaluation. Solution of aerodynamic, hydrodynamic and allied linear and non-linear problems of advanced nature. Investigation of fuel or gas flow and throttling in jet and turbine engines.
MATERIALS & MANUFACTURE	**Raw Materials** **Chemicals** **Minerals** **Mass Production** **Iron & Steel** **Textiles** **Food & Drink**	Full range of precision electronic instruments for all aspects of measurement in industrial research, development and production test. Choice of high-accuracy meter, oscilloscope or digital display presentation.	Process control simulation and analysis, analogue synthesis of all types of controlled power-driven equipment—paper, textile, bulk movement, etc. Chemical plant and refinery design, dynamic evaluation of complex problems.
POWER	**Nuclear** **Water** **Electricity** **Gas** **Steam** **Solar** **IC Engine** **Gas Turbine**	Instrumentation for supply testing and visual display. Stabilised conversion (AC-DC), and battery replacement (transistorised) bench units and sub-units. Vectorial measurement and analysis equipment. Test instruments for gyros, synchros, and servo-mechanisms.	Simulation of nuclear reactor controllers and basic reaction processes. Investigation of reactor thermodynamics and kinetics. Determination of critical and runaway conditions. Synthesis of power transmission networks.
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DATA HANDLING

Precision, ultra-high temperature pressure transducers; data logging, conversion, display and high-speed print-out equipment; industrial multi-channel magnetic tape recorder reproducer systems.

Transducers used by Bristol Aircraft in developing T.188

Data logging from test rigs of multiple variable parameters; high accuracy magnetic recording of local or telemetered data from aircraft or missiles; strain and pressure measurement instrumentation; high-speed digital recording from test rigs and prototypes.

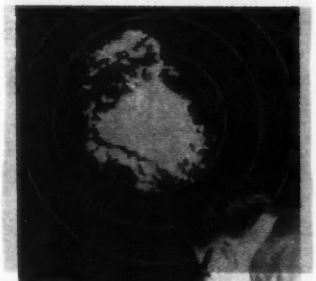
Precise measurement of pressures under exceptional conditions. Monitoring, logging and analogue or digital recording of process data for every industry. Programmed control of plant and processes by magnetic tape and associated error-sensing equipment.

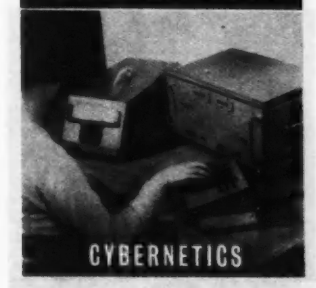
Continuous monitoring of supplies—electricity, water, gas, compressed air, etc. Digital logging for permanent record, digital display for remote supervision and control. Precise pressure measurement under extreme conditions.

RADAR Simulation

Training, tactical and special-purpose evaluatory radar simulators having the highest degree of display authenticity. For advanced training in, and appreciation of, military, naval, A.T.C., or marine navigation radars.

Air traffic control training and evaluation of new systems, training of air force, naval and merchant marine radar operators and controllers. Tactical training in manoeuvre or combat-air, sea, or combined operations.





Simulation means more concentrated training, more effective training—in radar appreciation, for control, navigation or defence. Simulated radar data can be fed to early warning systems to give vital recognition practice and heighten awareness under emergency conditions.

BUSINESS Machines

ERA, Electronic Reading Automaton, reading business information directly from original documents. Cybernetic-principle machines for accelerated training in manual co-ordination processes.

Accelerated training of morse, teleprinter, Teletypesetter and other operators by cybernetic training machines. High-speed recognition of printed data for transmission serially in any form over existing telecommunication or radio links.

Reading of p.s.v. ticket tally rolls for central data processing, providing traffic analyses and cash return information to operators in a fraction of the time previously required.

High-speed reading of tally rolls from public utility meter readers—gas, electricity, water. Provides more immediate and concentrated record for accounts and control needs, direct input information for computer assimilation.

High-speed serial reading of printed or typewritten characters for computer input use. In banks, insurance companies, Co-ops., Govt. departments, public utilities and all large organizations handling continuous-feed or separate document information sources.

Training for complex muscle-eye co-ordination tasks achieved immeasurably more quickly and effectively than by human instruction. Unsuitable pupils quickly assessed thus improving training economy factor.

AUTOMATION & Process Control

X-Ray Spectrometer—for continuous, accurate non-destructive analysis; Electronic Checkweigher for precise packaging control; programmed actuators; automatic warehousing order-filling equipment.

Control of transport fleet overhaul schedules by routine spectrometric analysis of IC engine oil, thus assessing accurately the wear of bores and bearings.

Continuous analysis and control by X-ray spectrometry down to Atomic No. 12—non-destructive, high-accuracy. High-speed electronic checkweighing of finished or cast parts integral with inspection processing.

High-speed electronic weighing of packaged foods, etc., at rates of up to two per second; automatic warehousing for institutional, wholesale or retail application—input demand renders listed items available inside fifteen seconds.

SYSTEMS CAPABILITY

...what SOLARTRON can do

It must be apparent from the pattern of the preceding pages that Solartron product lines are inter-related and complementary in application.

Continuous research and applications engineering in all these fields gives Solartron, now, a unique insight into present-day and future requirements of industry, resulting in a really soundly based *systems* capability—ability of the highest order to judge and advise in terms of tomorrow, to see the whole picture and do the whole job.

WHAT A 'SYSTEM' DOES

A 'system' is a purposive interconnection of electronic and other units, working together to solve a problem or to effect precise control in a specified way. Parts of an electronic system are concerned with measurement, others record, compute or compare. There may be—as in a controller which optimises a process—no visible output; or, for another application, measurements may be printed-out at a hundred a second. However the job is done, electronics gives you closer control, faster presentation of information, points up trends—gives timely warning of deviations. In the sphere of training, electronics is essentially impartial, flexible—a dozen blocks ahead of human teaching; for communicating information electronic techniques are instant and error-free. Learn how your industry can use electronics—ask Solartron.

CLOSING THE GAPS

Solartron, in addition to continuously programming expansion in the field of precision measurement and display, have repeatedly 'broken through' in research; in 'ERA', to clear the bottleneck at digital computer inputs; in 'SAKI', which uses advanced cybernetic principles to speed operator training—plus a host of advances in magnetic recording, analogue-to-digital conversion and very-low-frequency dynamic analysis. Tiny pick-offs which faithfully transmit intelligence under extreme conditions are in production at Farnborough by methods which give new meaning to the word precision. Radar simulators, automatic X-ray analysers, high-speed printers and a new generation of 'learning' machines too, are in production in this ultra modern manufacturing plant.

Whatever the skills and types of 'know-how' needed to find the best solution to a systems problem, benefit from continuous cross-fertilisation of ideas—talk to Solartron experts in O & M, data processing, mass manufacture and process control, automation, computing, simulation or training. Then let us advise you, whatever your industry, on the best solution to the measurement and control problems you see ahead.

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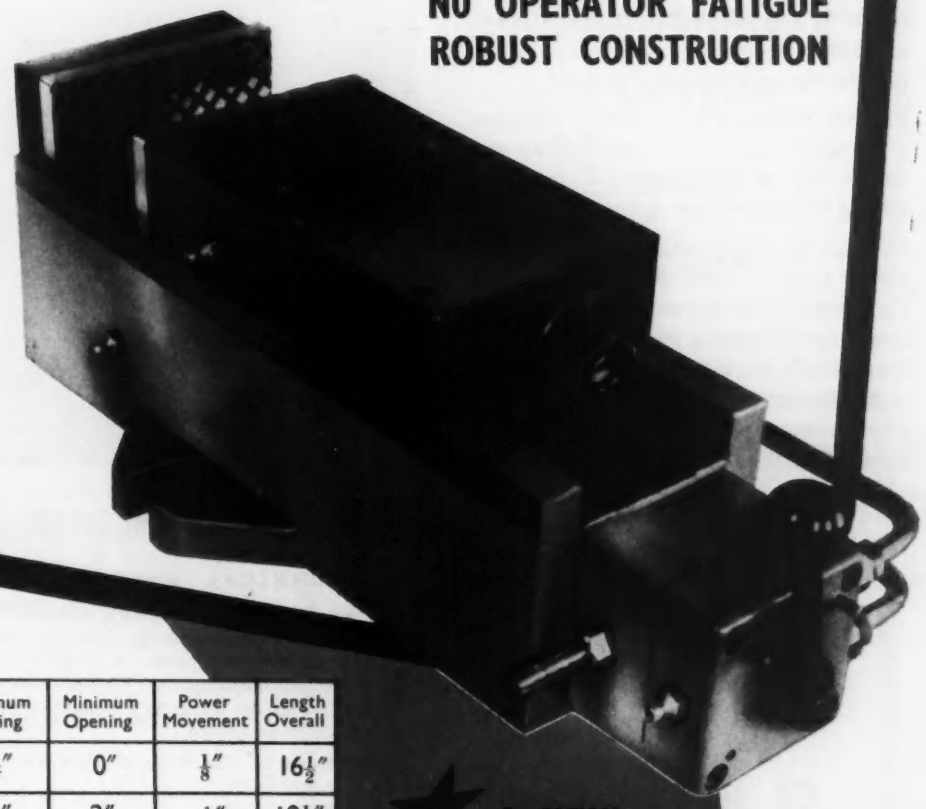

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At once you would be impressed by their reliability and adaptability to miniaturised electronic equipment, wherever a small general purpose blower is needed.

Plannair Wafters offer the Design Engineer a compact, lightweight, streamlined and particularly silent answer to problems arising from localised 'hot spots'.

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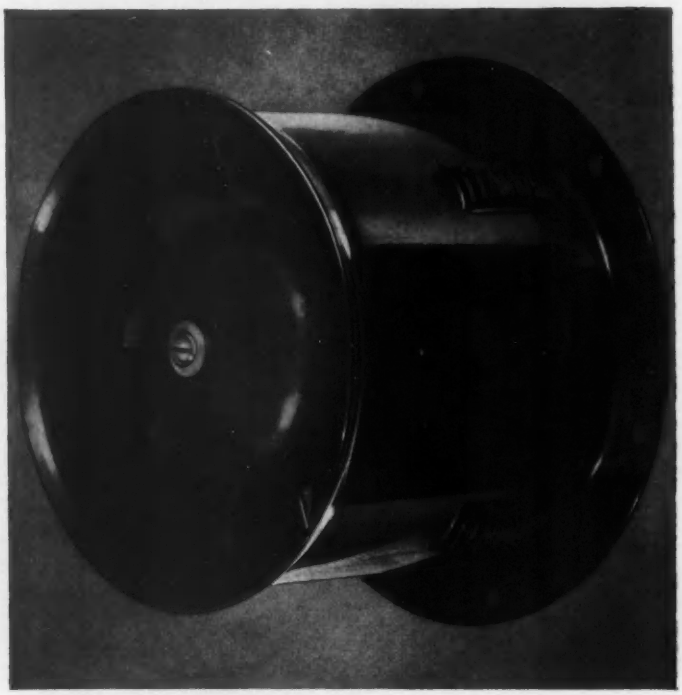

The Plannair Wafter Unit 3PL101-409

TECHNICAL SPECIFICATION:

HOUSING Designed to comply with the Ministry of Aviation requirements to meet the Specification No. 1086B for tropicalisation. In light alloy anodised finish incorporating black moulded rubber resilient mouldings for supporting motor. Terminal block mounted on outside.

DIMENSION 3½" long, 4" dia. over bell mouth, 4¾" dia. over rear flange.

WEIGHT 1 lb. 6 oz.

IMPELLER Moulded fibre glass.

MOTOR Shaded pole type wound for 110/115 V or 230 V single phase 50 cycles. Consumption 12 watts.

PERFORMANCE 50 c.f.m. under free air conditions.

SPEED 2,600 r.p.m.

NOTE: *The Plannair Wafter is available in a number of alternative housings. Send for the Plannair Wafter leaflet which gives full details of units available.*

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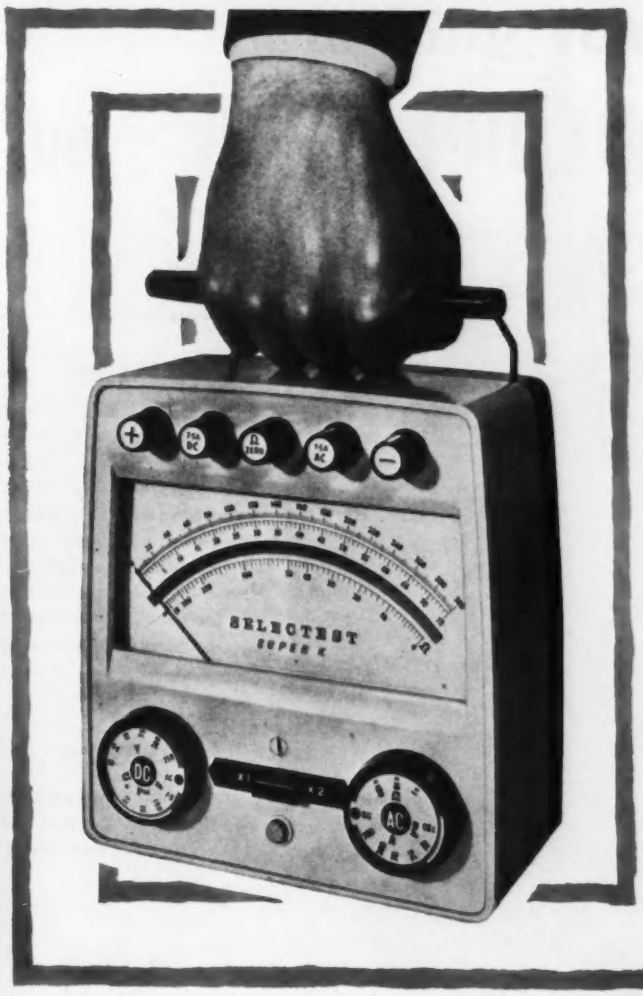

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Accurate readings can be taken with the instrument in any position. The resistors, rectifier, transformer, movement, switches and automatic cut-out are mounted on a robust printed circuit board, enclosed in a strong attractive, two-tone dustproof case, with a unique carrying handle.

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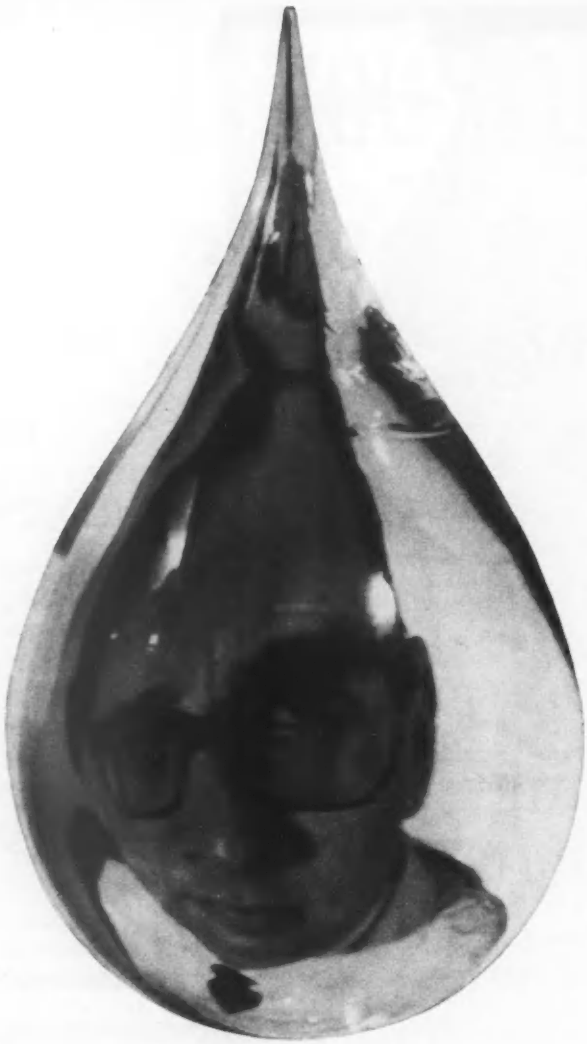
STAND E.211

I.E.A. EXHIBITION



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The AIRMEC PROXIMITY DETECTOR

TYPE N266

The Proximity Detector Type N266 is a capacity-operated switch with a wide range of application in the fields of measurement and control. It is operated by any physical variable appearing as a small movement. The equipment consists of a control unit housed in a robust cast light-alloy industrial case, sealed against the ingress of dust and moisture, together with a sensing probe. The probe which contains no electronic components and is therefore unaffected by heat or rough treatment, may be fitted with a cover for use in liquids or corrosive atmospheres.

★ HIGH STABILITY

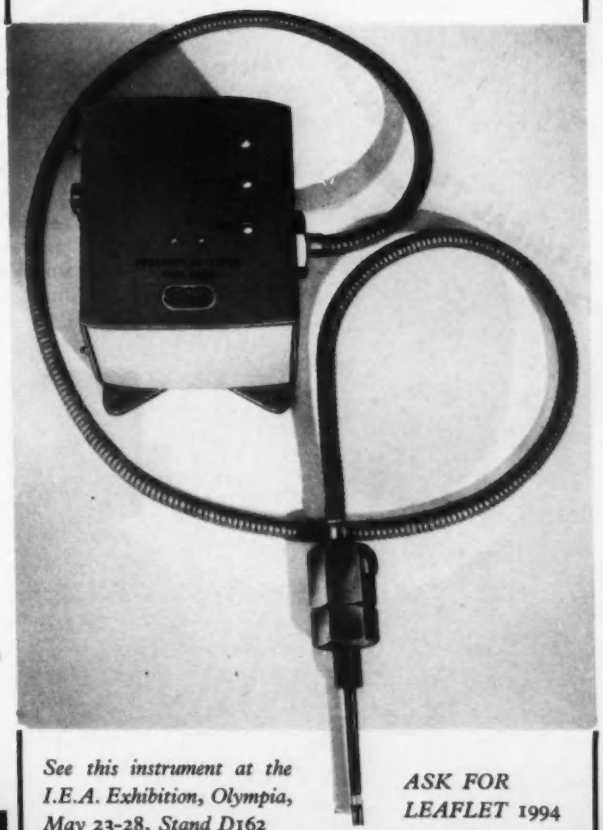
Even when the highest sensitivity is in use, mains voltage variations over the range 180-260 volts and temperature changes of 20° can be tolerated without significant change of operating point. This means that once the equipment has been initially set up it will need no further attention.

★ RELIABILITY

A transistorised printed circuit is employed for its high reliability.

★ MAINS OR BATTERY

Either a mains power unit or a battery unit is fitted to order. Under maximum current conditions the battery life is excess of 200 hours, at 4 hours per day, but in many applications the battery life may well be extended to the shelf life.



★ EXCEPTIONAL SENSITIVITY

Its sensitivity is such that it will detect a capacity change of 0.05 micro-microfarad, representing a movement of the order of tenths of thousands of an inch under suitable conditions.

★ PROBES

A variety of probes (fixed or remote) are available for a wide range of applications.

★ WIDE APPLICATIONS

Level control and counting, sorting, grading, gauging, limit switching and any application involving the detection of small variations in the position or nature of both conductors and insulators.

See this instrument at the I.E.A. Exhibition, Olympia, May 23-28, Stand D162

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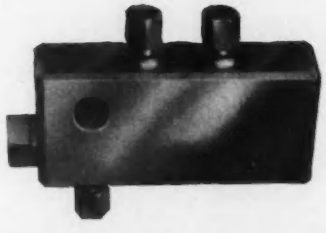
HML MECHANICAL TRANQUILLISERS
CALM DOWN YOUR SYSTEM

Here are two useful products that help you make the most of a single supply hydraulic system.

HML AUTOMATIC GAUGE ISOLATOR

Protects Gauges from sudden surges beyond their capacity. The adjusting screw is set to isolate at 90% of the gauge full scale reading. Fit a number of pressure gauges together with their appropriate isolators and obtain a very accurate indication of pressure throughout the entire system.



HML VARIABLE PRESSURE REDUCER VALVE

The only pressure reducing valve on the market today that will maintain set reduced pressure under varying pressure and flow conditions. Pressure range 0-5000 p.s.i. Flow range 0-10 g.p.m.

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HML manufacture a wide range of high precision hydraulic test equipment. Please write for full details.

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the unsleeping eye

Hartons instrumentation and control systems provide a 'brain' to direct and record continuous industrial processes, an 'eye' that never sleeps

As sub-contractors a number of control cabins and instrument panels manufactured by Hartons Installations Limited are installed in the Durgapur Steelworks

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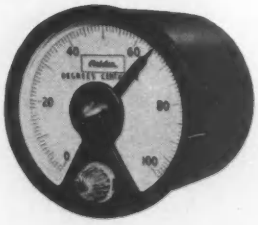
THE LATEST Fielden

The Bikini range of temperature instruments and the Electronic Control system are being exhibited for the first time, at the I.E.A. Exhibition. Anyone interested in the accurate, reliable control of process variables would be well advised to see our unique developments at Stand C110.

BIKINI temperature instruments

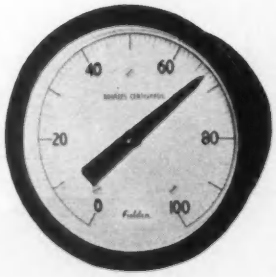
These are inexpensive transistorised instruments designed to operate with resistance bulbs. They provide the accuracy normally associated with much more expensive instruments. Their simple design gives even greater reliability.

PRECISION TEMPERATURE CONTROLLER



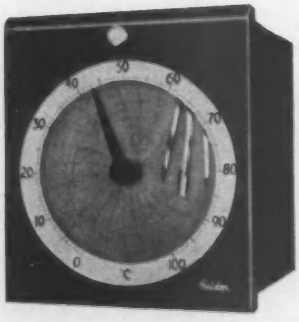
A completely sealed unit providing ON/OFF control action. The dial is accurately calibrated and the instrument can be up to 300ft from the measuring point without affecting its calibration. Available in many Centigrade or Fahrenheit ranges and with suppressed zero.

TEMPERATURE INDICATOR



Another completely sealed unit requiring no maintenance. This is a self-balancing indicator and can be fitted with a control contact. The price of this equipment and the economies which can be effected in installation make this a practical alternative to mercury - in - steel indicators.

TEMPERATURE RECORDER



The Recorder is a compact instrument which operates on the same principle as the Indicator. It can be fitted with control contacts of proportional control and its indicating scale is clearly readable from a distance.

THERMOCOUPLES

An equivalent series of instruments is available for use with thermocouples. These are self-balancing D.C. Potentiometers and the control facilities which can be fitted to the above recorders can also be fitted to these.

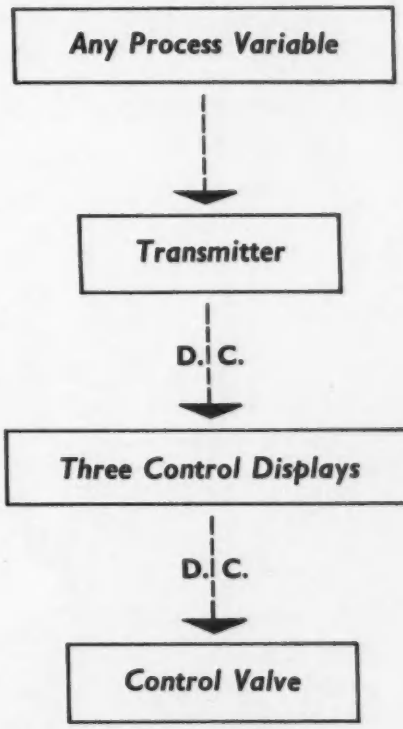
Fielden

n DEVELOPMENTS

STAND C 110
I.E.A. EXHIBITION

electronic control system

- ★ **Complete system from variable to control valve**
- ★ **D.C. Transmission free from effects of Pick-up and lead length**
- ★ **Safe, low energy transmitters on plant**
- ★ **Moving coil meters can be used for indication**
- ★ **Choice of three displays when using controller**
- ★ **Complete flexibility for use in hybrid electronic/ pneumatic systems**
- ★ **Drift free controllers**
- ★ **Extremely low maintenance**
- ★ **Low capital cost**
- ★ **Low installation cost**



IMPORTANT NOTE

Whilst all the units have been designed to fit into the complete system individual units often provide the most economical solution to particular measurement problems. For example, remote indication of temperature, pressure level flow, etc. can be achieved with just the appropriate transmitter and a moving coil meter.

Also on show . . . . .

LEVEL CONTROLLERS AND INDICATORS
A comprehensive range of capacity operated instruments including the latest versions of the well-known Tektor Controller and Telstor Continuous Indicator.

MULTIPOINT TEMPERATURE INDICATOR
Equipment for indicating up to 50 pts. at temperature from below 100° C to above 1600° C.

TRANSISTORISED SERVOGRAPH RECORDER
Compact, inexpensive, servo-operated recorder with minimum range 0-25 microamps D.C.

FOUR POINT RESISTANCE THERMOMETER
Transistorised instrument using resistance bulbs. Particular features are its stability and very high reproducibility.

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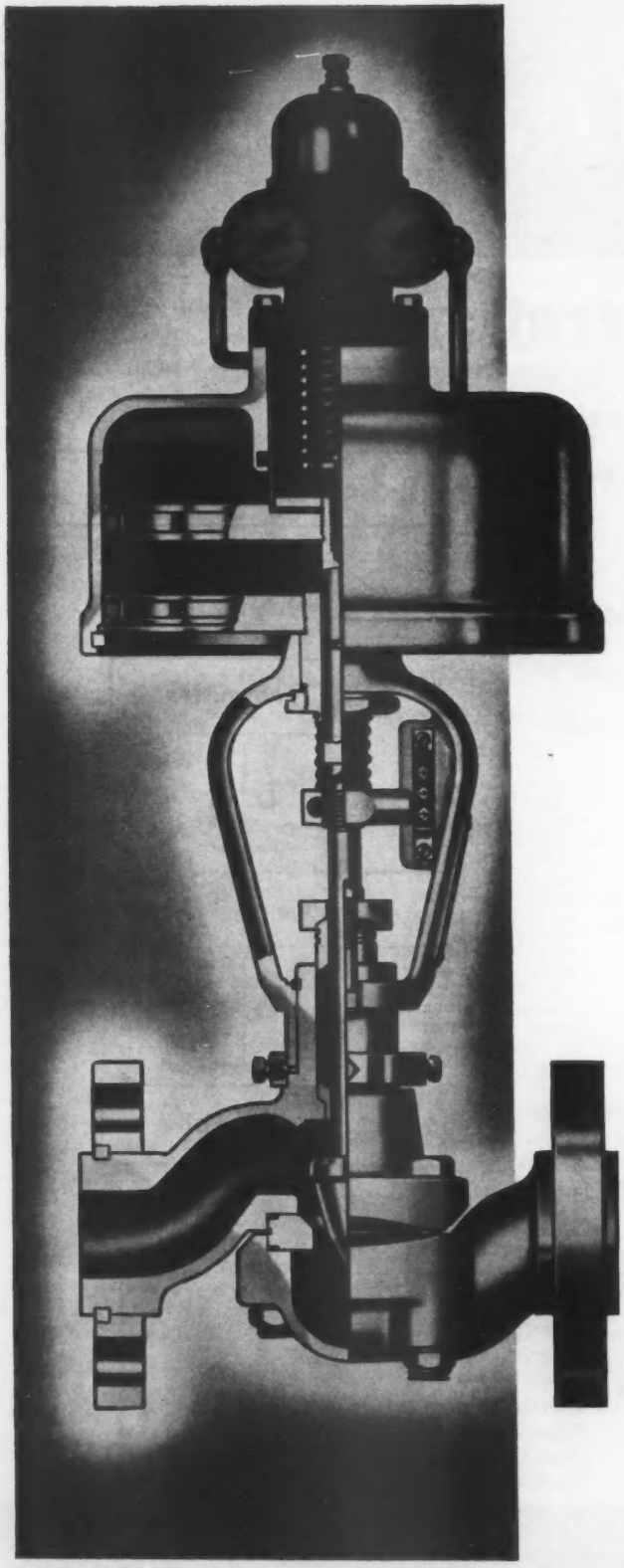
Indicating
Recording
Control

THE ANSWER TO CONTROL PROBLEMS



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DOMOTOR CONTROL, CYLINDER AND HANDWHEEL OPERATED. IN SIZES ½" TO 10"

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THE DOMOTOR

supersedes the conventional diaphragm and spring type servo-motor. A power piston with integral positioner, the Domotor is capable of: –

- ★ Positioning the valve with an accuracy measured in thousandths of an inch, regardless of varying stem forces.
- ★ Longer stroke allows improved trim design.
- ★ Equal power available throughout the stroke.
- ★ Supplied with side-mounted-handwheel if required.
- ★ Will open or close on main air or 3–15 psi instrument air failure. Available to 'open' or 'close' on increasing signal pressure. The Domotor can be readily converted to either application on site.

AUDCO ANNIN Valves

Used to operate Audco Annin Control Valves of up to 2500 ASA rating.

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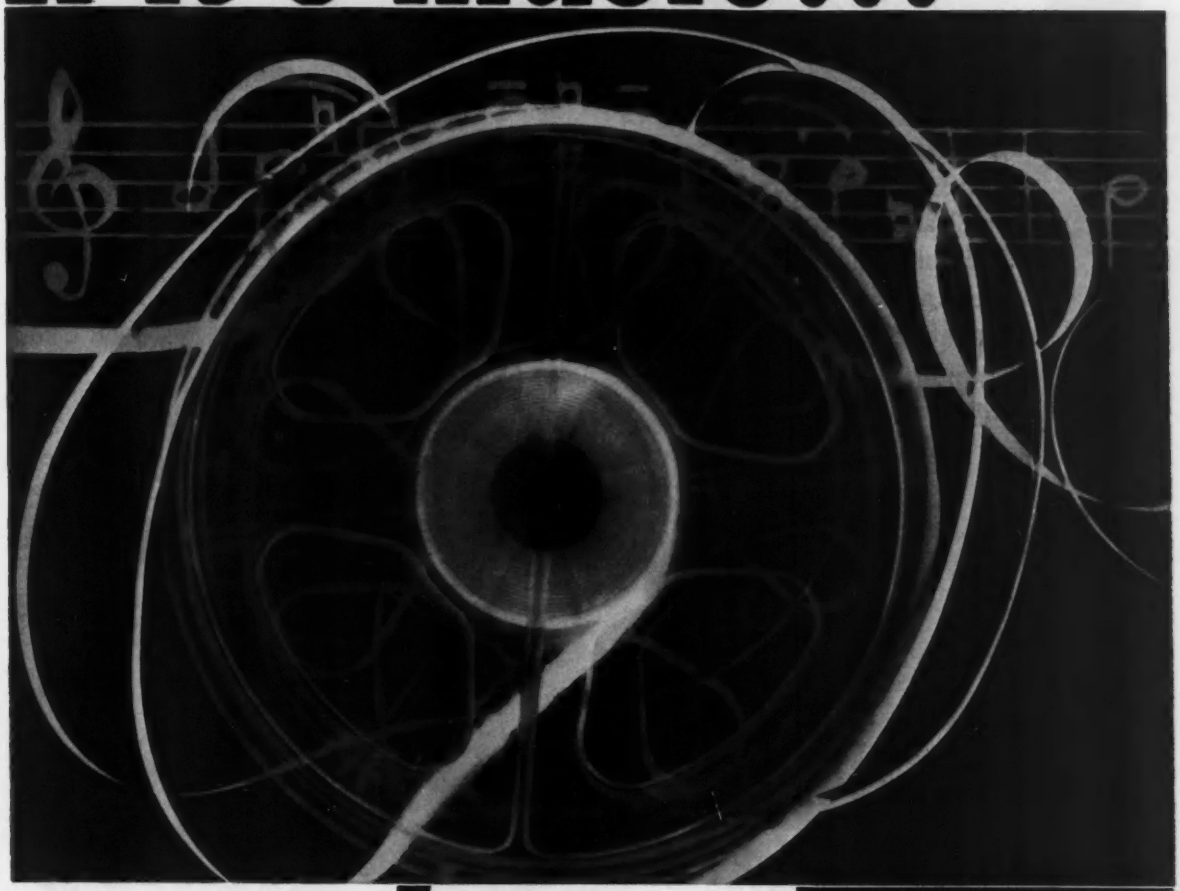
A Division of Audley Engineering Co. Ltd. Newport Shropshire

If it's music...



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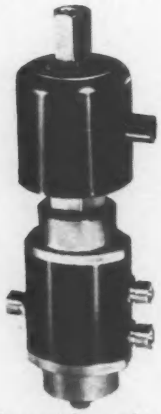
CONTROL VALVES *with Solenoid or Diaphragm operation*

Steady development of solenoid and diaphragm-operated valves has produced a large number of models suitable for controlling gas and oil fuel.

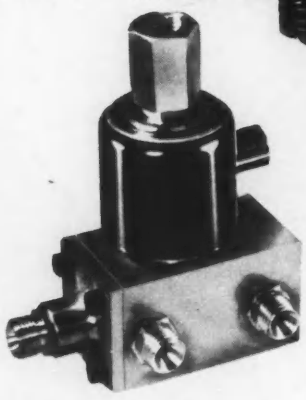
Valves for general control applications (pneumatic and hydraulic) and highly specialized uses (guided missiles) are also available in an increasing number of types to meet modern technical requirements.

Designed for use on hydrogen at operating pressures of 14,500 *psig. Test pressure* 22,000 *lbs. psig. (DOLV.)*

Solenoid gas valves up to 6" BSP (threaded or flanged connection). (LG. series.)



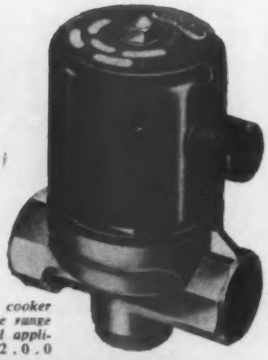
High-pressure 3-way valve up to 4000 psi for missile and machine tool applications. (TW/VHP.)



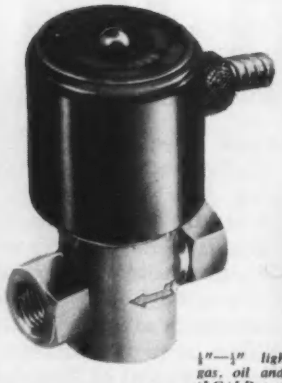
Miniature 4-way air valve for double acting power cylinders. (FW2.)

OHV gas valve specially developed for controlling radiant gas heaters (in co-operation with Horstman Gear Co. Ltd.).

Miniature gas pilot valve (LGM.). £1 . 0 . 0



Specially developed for gas cooker use, and suitable for a wide range of domestic and other small appliances. (AVG.) £2 . 0 . 0



¼"—½" *light duty gas, oil and air valves (LG/LD series* £2 . 10 . 0).

Solenoid-operated lever valve with reversible cage giving direct or reverse action at will. For high viscosity oils. (HDOL.)

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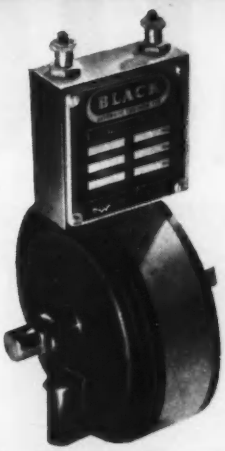
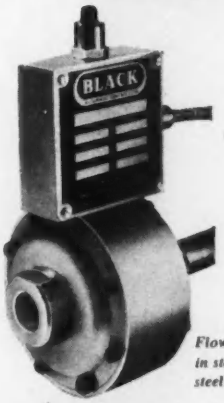
Characterised by small but robust switch action rated up to 5 amps, the Black range caters for pressure signalling and control functions for all kinds of industrial applications including missile and nuclear energy requirements



Differential pressure switch incorporating two diaphragms giving operation at very small differentials and very high pressures — fully adjustable. (DPS. Mk. II.)

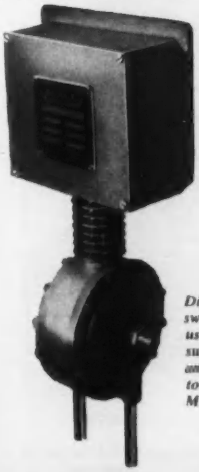


Flow switch in stainless steel. (FSW.)

Constant flow valve designed for controlling the flow of oil to burners fed by ring main for the Steel Industry. (FCV.)

High pressure switch for the range 200-10,000 psi, fully adjustable. (VHPS.)

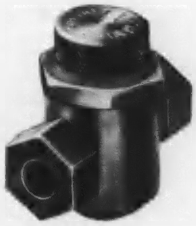
Miniature pressure switch for sequence operation, can be provided with up to six switches to operate at different pressures. (VPS/MU.)



Differential pressure switch developed for use on CO_2 at pressures up to 250 psig and temperatures up to 350°C. (DPS Mk. II/s.)

Low pressure switch 1"-30" wg with adjustable differential. (LPS.)

Miniature fully adjustable pressure switch for air, oil, etc., up to 200 psi. (VPS/A.)



Miniature pressure regulating valve for air or water pressures up to 140 psi. (PRU.)

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Solenoid operated rotary selector and power switches

The latest development in Style C-switches is the multi-position rotary power switch with solenoid operation, which replaces power relays. This unit occupies far less space than other control systems; it simplifies wiring, assembling and servicing. It carries out the operations triggered off by limit switches, timers or push buttons without those banks of relays, and its uses include:

- Automatic sequencing of machine tools
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- Automatic motor starting
- Changeover in power supplies, etc.

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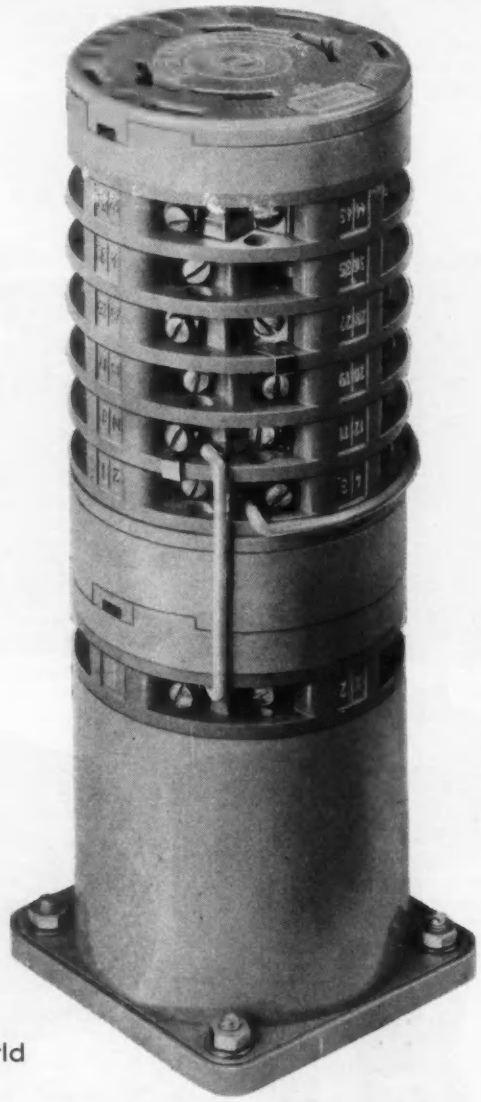

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The most versatile switches in the world

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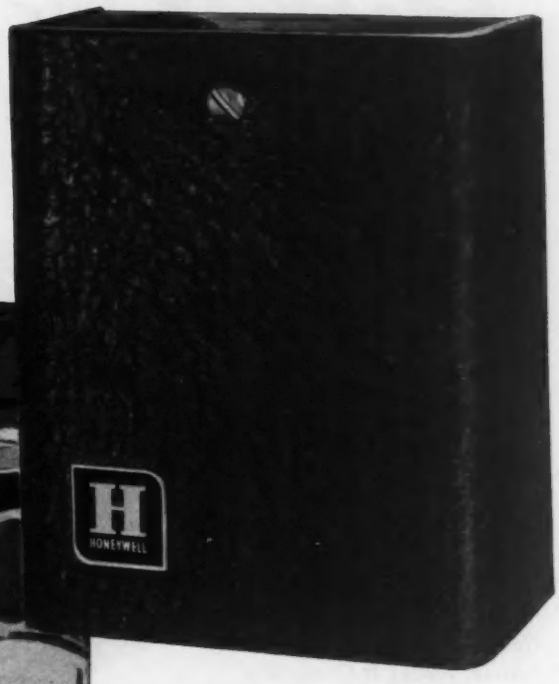
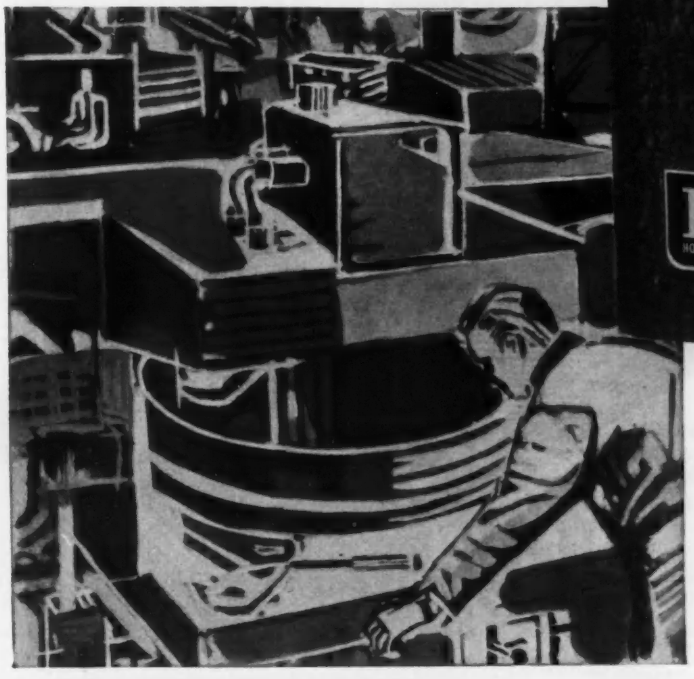
a compact inexpensive electronic controller





for Temperature–Liquid level

Now, the Versa-Tran — a transistorized controller that's versatile enough to be used in many applications. Small, compact, no valves, no warm up time, gives instant reaction. Works with sensors that can be thermistors or probes. Can be used in such varied applications as packaging machines, injection moulding machines, cooking vats, tyre retreading, and tank level, etc.
Has a temperature control range from —60°F. to +500°F.
The Versa-Tran is the result of traditionally superior Honeywell engineering.

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Sales Offices in the principal towns and cities in the United Kingdom and throughout the world.

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Here is a 12v. stabilized d.c. supply at 4 amps!

How to obtain high current constant voltage D.C. supplies?

You could use cumbersome batteries with their need for constant attention, but it is far simpler and certainly more reliable to use one of the new 'Advance' Constant Voltage D.C. Supply Units. This latest development in the application of Constant Voltage Transformers can be used to provide various d.c. supplies up to quite high current levels, as used in computers and data processing equipment. We shall be pleased to arrange for one of our technical representatives to call and discuss your requirements.

These new D.C. Supply Units . . . .

- **Provide HIGH CURRENT OUTPUT AT LOW COST**
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DC.1	6 volts	1.25 amp	£20
DC.2	6 volts	4.00 amps	£25
DC.3	12 volts	1.25 amp	£20
DC.4	12 volts	4.00 amps	£27
DC.5	24 volts	1.00 amp	£20
DC.6	24 volts	5.00 amps	£30
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Advance CONSTANT VOLTAGE

D.C. POWER SUPPLIES

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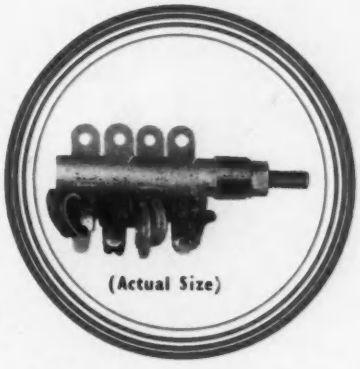

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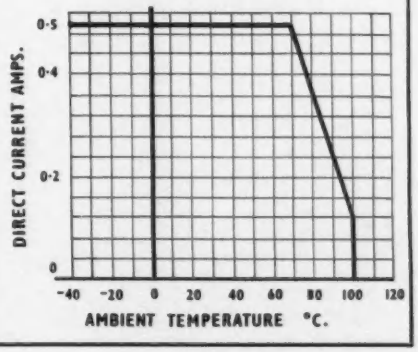
RATINGS (UP TO 2400 C/S)				
CODE	ABSOLUTE P.I.V. RATING	V r.m.s*	I.D.C. MAX.	TEMP.
IB000	100	35	0·5	70°C
IB001	200	70	0·5	70°C
IB003	400	140	0·5	70°C
IB006	800	280	0·5	70°C

* FOR DIRECT MAINS OPERATION DERATE BY A FACTOR OF 2.

CURRENT DERATING CURVE



Joseph Lucas Ltd

● *For prices, applications and further details apply*

G. & E. Bradley Ltd

SEMI-CONDUCTOR DIVISION · *Telephone* Gladstone 0012

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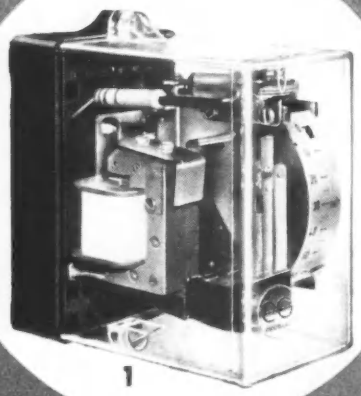

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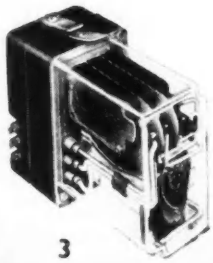
2



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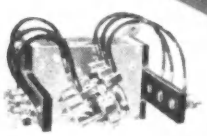
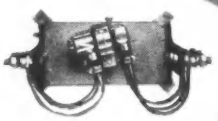


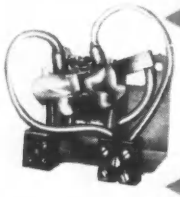
MEDIUM DUTY MERCURY SWITCH CONTACTORS

Available in 60 and 75 amp. T.P. and N. Coils wound for any specified voltage, supplied as open type, with metal dust cover or in weatherproof box. *Please write for catalogue 'Relays and Contactors'.*



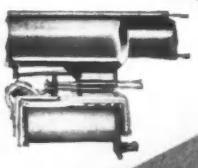
HEAVY DUTY MERCURY SWITCH CONTACTORS

Available in 100, 150 and 200 amp. T.P. and N. Coils wound for any specified voltage. Supplied as open type, with metal dust cover or in weatherproof box. *Please write for catalogue 'Relays and Contactors'.*



'H' SERIES RELAYS

A compact, well constructed unit at a very economical price available in 3 amp. triple pole, 5 or 15 amp. double pole and 30 amp. single pole. *Please write for leaflet "'H" Series Relay'.*



HIGH VOLTAGE VACUUM SWITCH

These can be mounted on "G" series relay or supplied separately, switching capacity 2 KV. at 2,000 watts, A.C. or D.C., non-inductive load, with inductive load 100 watts. Small in size and economically priced. *Write for leaflet "High Vacuum Switch".*

1. PROCESS TIMER

This unit embodies a synchronous motor wound for 240 volts A.C. and clutch mechanism, is provided with four change-over contacts rated at 6 amps., 240 volts A.C., and adjustable from 0·3 seconds to 6 hours.
Write for leaflet E.G. M.Z.11.

2. SEALED MERCURY RELAY

This relay is the sturdiest yet designed, constructed almost entirely of steel and ceramic materials, without any glass parts. It can be operated in any direction within 50 deg. of the vertical line. This unit will withstand momentary short circuits without damage.
Write for leaflet E.G. S.R.12.

3. MICRO SWITCH RELAY

The contacts of this relay are totally enclosed and the coil operation is especially constructed to operate on A.C. supply, the unit can be mounted in any position. Contacts are rated at 6 amps. single, double and triple pole change-over.

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FG. 303/2

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Data Processing

The new Hagan Kybernetes System enables a new approach to the problems of scanning, logging, alarm scanning, optimising, programming and other general requirements of data processing systems.

Of modular construction and utilising solid state components, the system features optimum reliability with such flexibility that a new dimension is added to data processing.

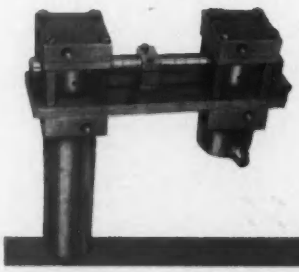
In its basic form, the system is a simple logging unit for recording process data on a log sheet or other output device. The modular construction facilitates expansion and is in keeping with the Hagan approach to computer control, which, in broad principles, requires the following progressive steps:

- ✳ Installation of a solid state electronic analogue control system.
- ✳ Installation of a solid state electronic scanning/logging data system.
- ✳ Installation of computer capacity to compute from processed data.
- ✳ Use of computed data to optimise analogue control loops.
- ✳ Addition of programming for automatic starting/stopping and day-to-day operation.

The Kybernetes system is readily adaptable to fulfil these requirements and offers a truly economic means of obtaining self-optimising process control.

Pneumatic Equipment

The Hagan range includes pneumatic signal transmitters for pressure, temperature and flow measurements and a unique pneumatic relay whereby the signals from such transmitters may be added, subtracted, averaged, multiplied or divided in any desired manner. The Hagan Ratio Totaliser is a pneumatically operated control mechanism for accurately combining input signal pressures and spring forces to produce a single output signal pressure. The output represents the desired combination of the input signals. A maximum of three input signal pressures plus three spring forces can be accommodated in a single unit.



HAGAN

HAGAN CONTROLS LIMITED

To provide British Industry with the service and equipment required for all aspects of automatic control, a new Company has been formed.

LIMITED

HAGAN CONTROLS LIMITED embodies the considerable development facilities and resources of The Plessey Group of Companies with the unique operational experience and 'know-how' of Hagan Chemicals & Controls, Inc., one of America's leading producers of instrumentation and control systems for combustion applications, industrial processes, aeronautical test gear and similar specialised equipment.

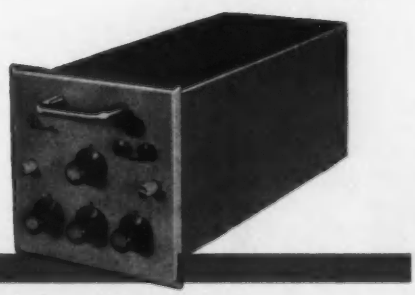
Hagan designs embody wide range adjustment to suit site requirements and it has been found that standard units can usually be applied immediately to individual and complex applications. Furthermore, although the majority of Hagan Control components have been primarily designed for operation in Hagan auto-control systems, individual components have demonstrated a remarkably wide range of versatility in other applications.

Electric and Electronic Equipment

The use of electric and electronic control elements for process control applications is steadily growing by virtue of simple installation and the virtually instantaneous transmission which is inherent in an electric system.

An expanding range of Hagan electric control equipment includes pressure, flow, and motion transducers, and the "PowrMag" solid state analogue computer control which is shown here.

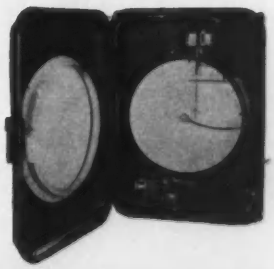
The Hagan "PowrMag" system employs magnetic amplifiers in analogue computer technique, thus ensuring long and maintenance-free service with completely static equipment. The "PowrMag" system represents the most advanced approach to a universal solution of industrial process control problems.



Hagan Ring Balance Flow Meters, Transmitters & Receiving Indicators

These equipments provide an answer to all problems connected with fluid flow measurement, control, and recording. They provide an indication of flow rate with an accuracy of ±0.5% of full scale range down to 10% of full scale and are sensitive from 10% to zero. The Hagan range of receiving instruments may be used in conjunction with a ring balance flowmeter, pressure transmitter, a resistance thermometer bulb or other suitable electrical element.

Hagan Pressure Recorders such as Type 6001 illustrated here can embody pressure elements ranging from 0–20″ WG to 0–3000 lb. sq. in., or a considerable number of combinations, including pressure and temperature compensating features and a pneumatic transmitter or controller.



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H2

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VOLTAGE	0 to 500 V.	250 V.	0 to 250 V.
CURRENT	0 to 250 mA.	0 to 100 mA.	0 to 1 mA.
STABILISATION	15 mV.	15 mV.	15 mV.
RIPPLE	1 mV.	500 μV.	500 μV.
A.C. OUTPUTS	Two outputs at 6·3 V., 5 A.		
MAINS SUPPLY	200 to 250 V., 50 c/s in 10 V. steps		

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Specification Per Unit

OUTPUT VOLTAGE	± 0 to 30 V.	OUTPUT CURRENT	0 to 1 ampere
OUTPUT RESISTANCE	0·01 ohm	STABILISATION	1500 : 1
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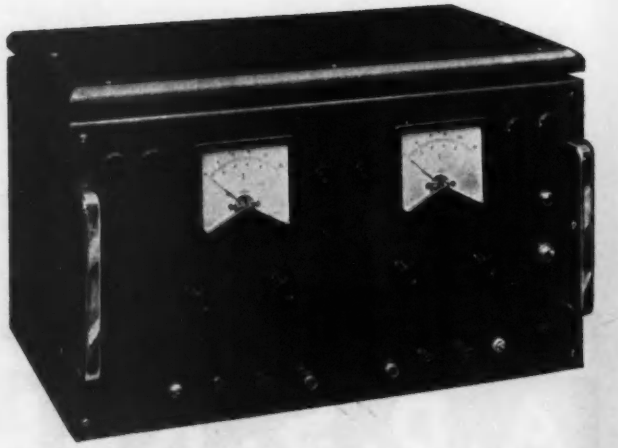

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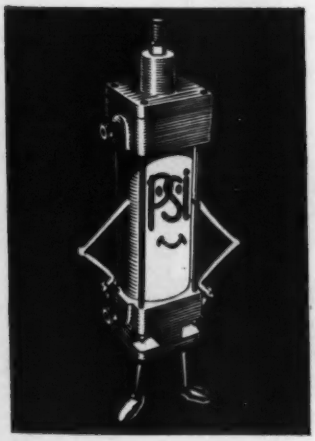

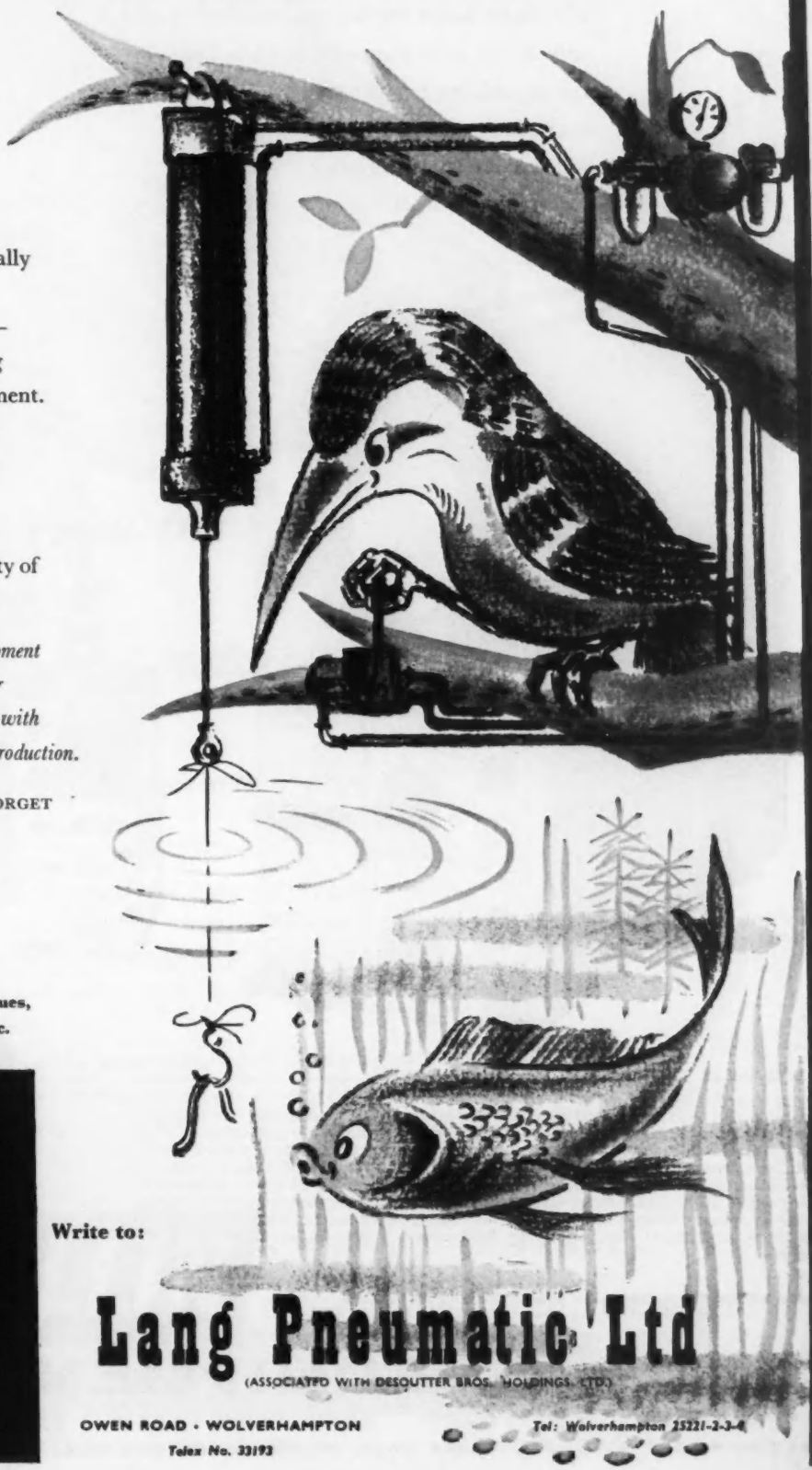

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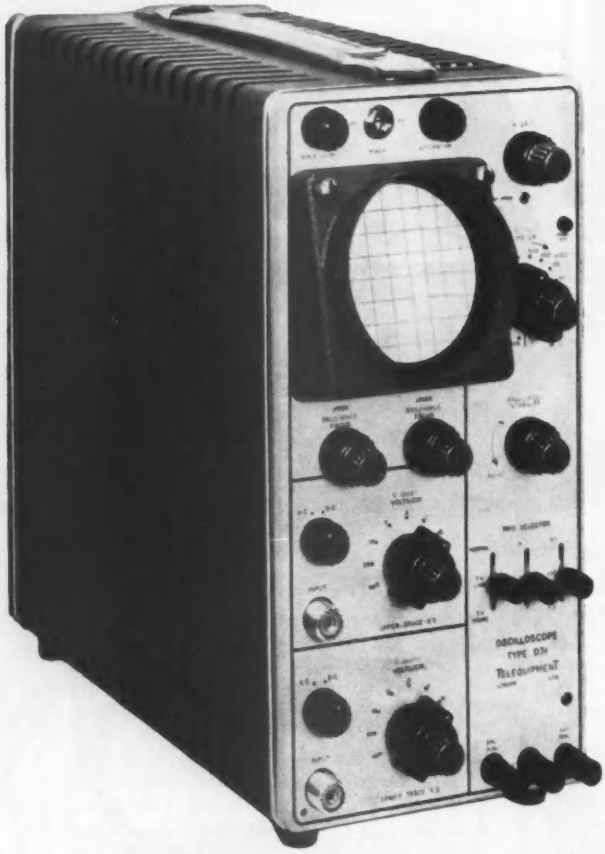

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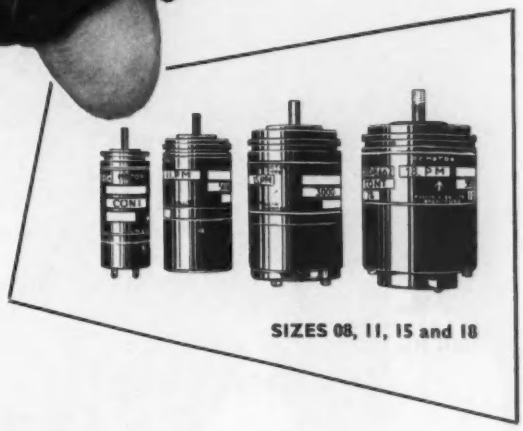

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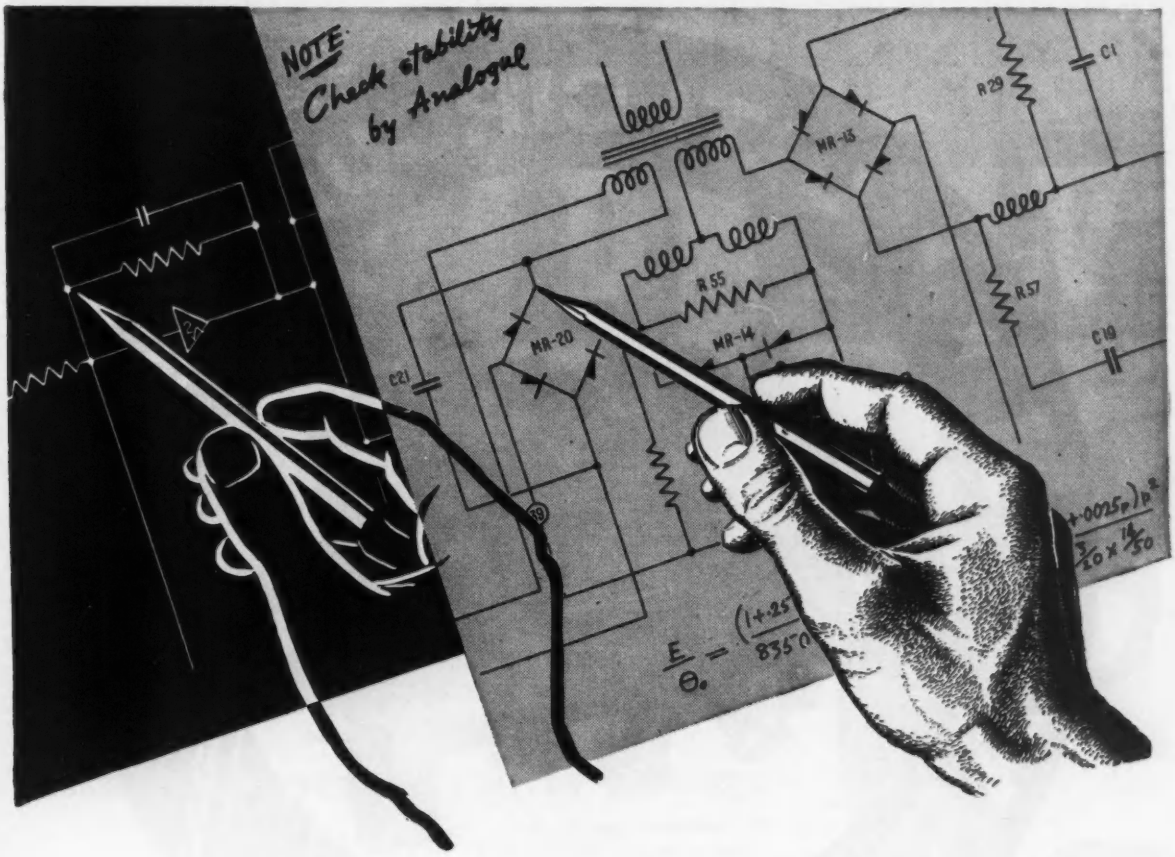

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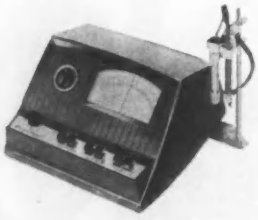

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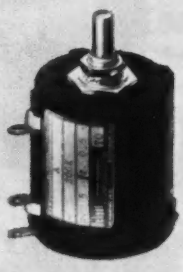

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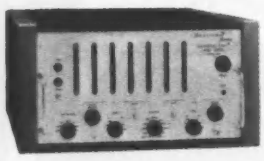

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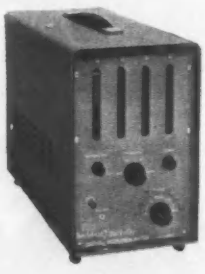

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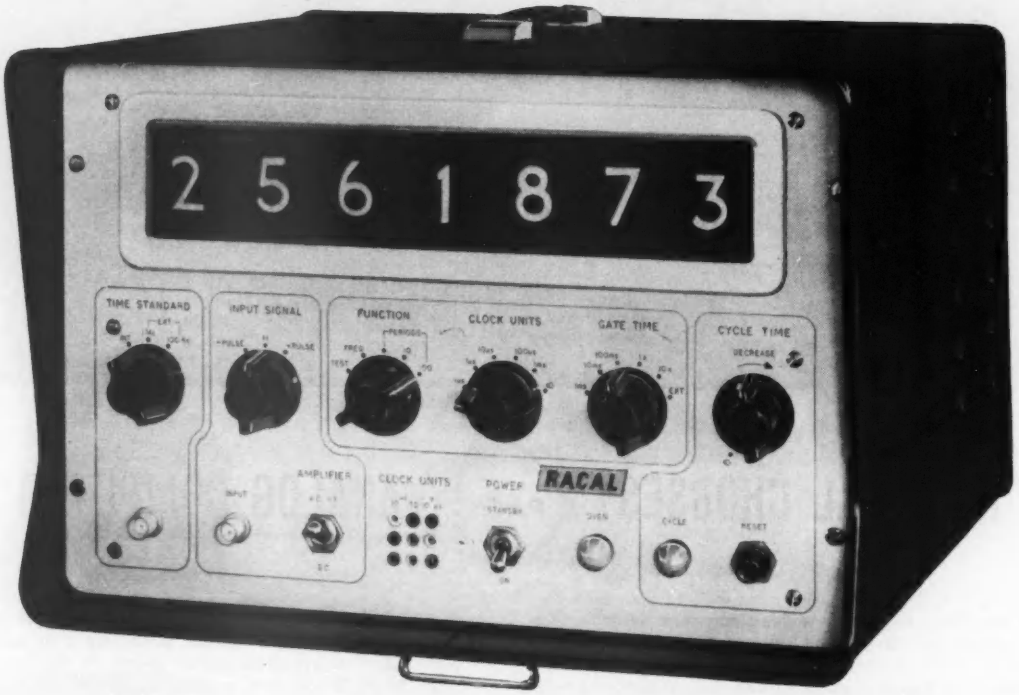

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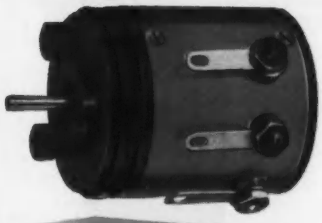

MODEL C

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It is available with 10 different wiring variations of which one is illustrated.

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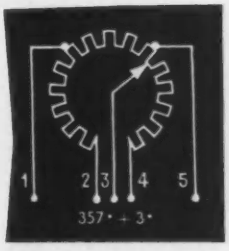
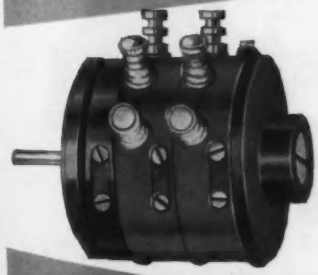
Resistance Range 200 to 750 K ohm
Power Rating 1 watt
Temperature Range −55°C to +85°C
Max. Operating Speed 500 r.p.m.
Noise < 2μV

The above data applies to a standard linearity of 0·5%, but linearities of 0·25%, 0·15% and 0·10% are available.





MODEL H

The H Series is primarily intended for those applications where multi-element precision potentiometers are essential. All models can be delivered adjusted to the required angle.

Elements are available with 7 different wiring variations.

Running Torque 0·5 g/cm per element
Resistance Range 200 — 50 K ohm
Power Rating 0·5 watt
Temperature Range −55°C to +85°C
Max. Operating Speed 500 r.p.m.
Noise < 2μV

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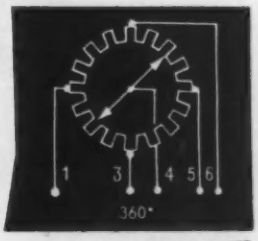

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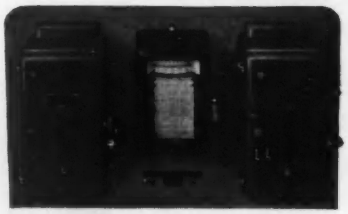

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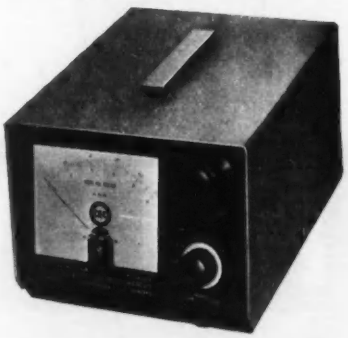
Detects from trace amounts to 100%. This new analyser which is suitable for both laboratory and process applications is now available in this country. Over 1,000 instruments have already been supplied. Write for further information.



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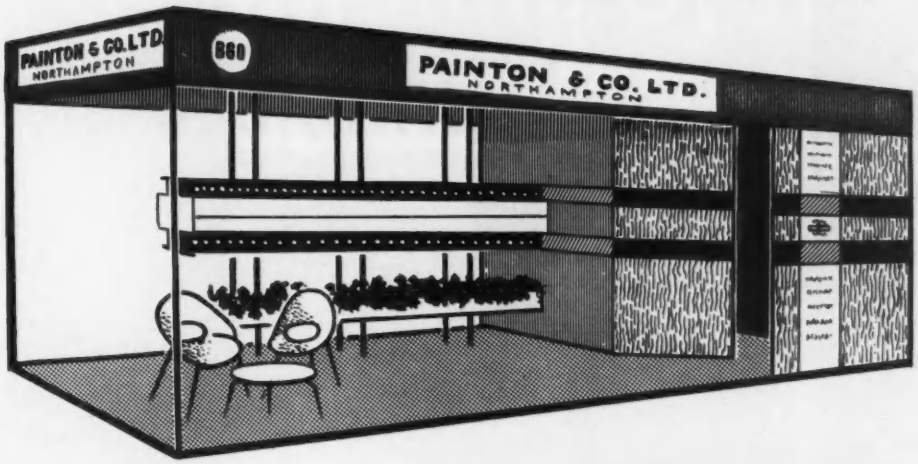
Types 26-301 and 26-302 Portable Moisture Monitors measure moisture in gas from less than 1 ppm to 1000 ppm and 20,000 ppm respectively. The 26-350 series High Pressure Moisture Monitors can operate at pressures up to 10,000 psig. Write for Bulletins 1834 and 1855.

PLANT CHROMATOGRAPHY

Type 26-202 Process Chromatograph. Outstanding features of this instrument include pre-cut column, explosion proof bell, vaporiser regulator, automatic zero adjustment, continuous variable attenuation and bar graph presentation. Fully automatic control systems are available for use with this analyser. Write for Bulletin 1836C.

STAND NO.

B 60



Stand B 60
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Electronics &
Automation Exhibition
Olympia—
May 23—28

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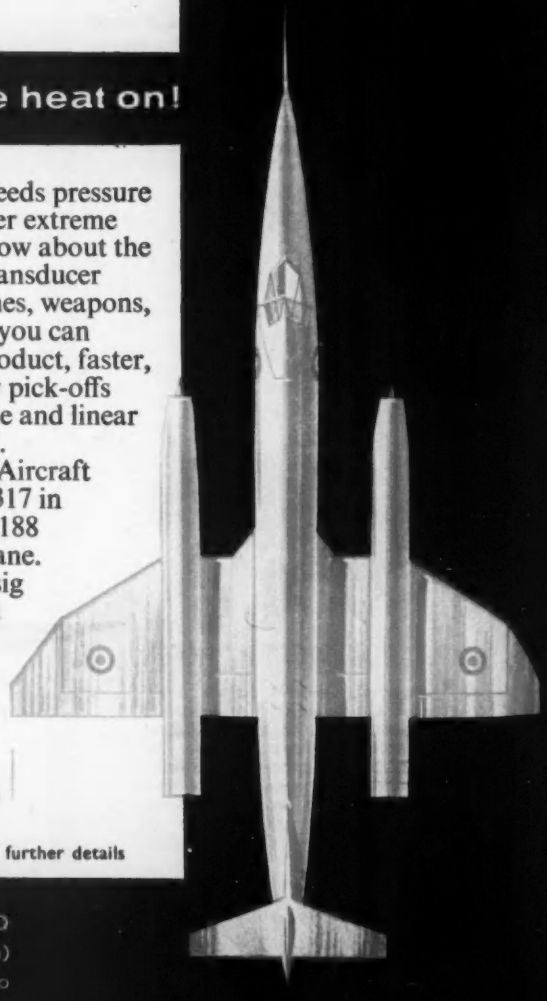
Small wonder then that Bristol Aircraft Limited chose the NT. 4-317 in developing their outstanding T.188 supersonic research aeroplane.
Pressure ranges are from 100 psig to 5,000 psig, compensated temperature range is −65° F to + 600° F.



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294736	910485
271057	839120
984752	856321
379824	658493
105447	539582
459233	937562
811278	423038
532485	902475
114857	521054
984735	284731
927411	883746
210473	937561
567482	109235
665820	991375
857395	274837
948573	198573
195847	958473
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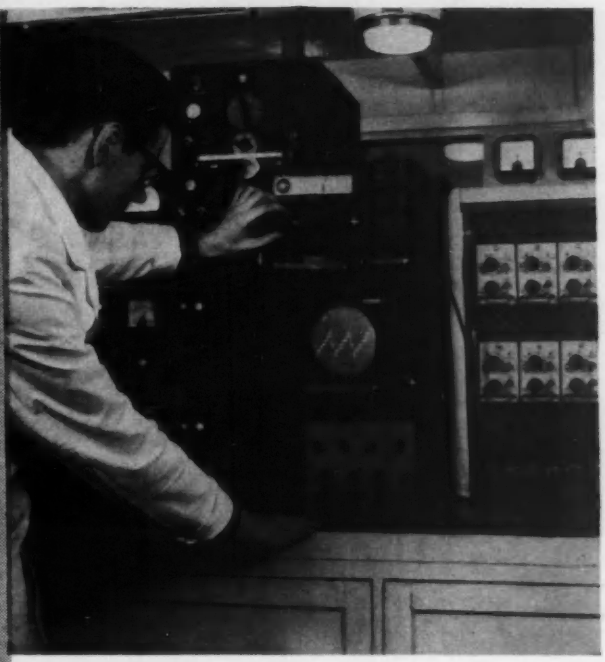
772689	921006



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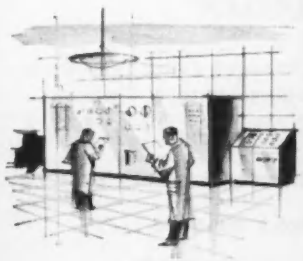
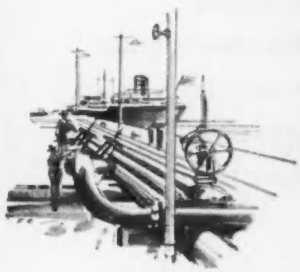
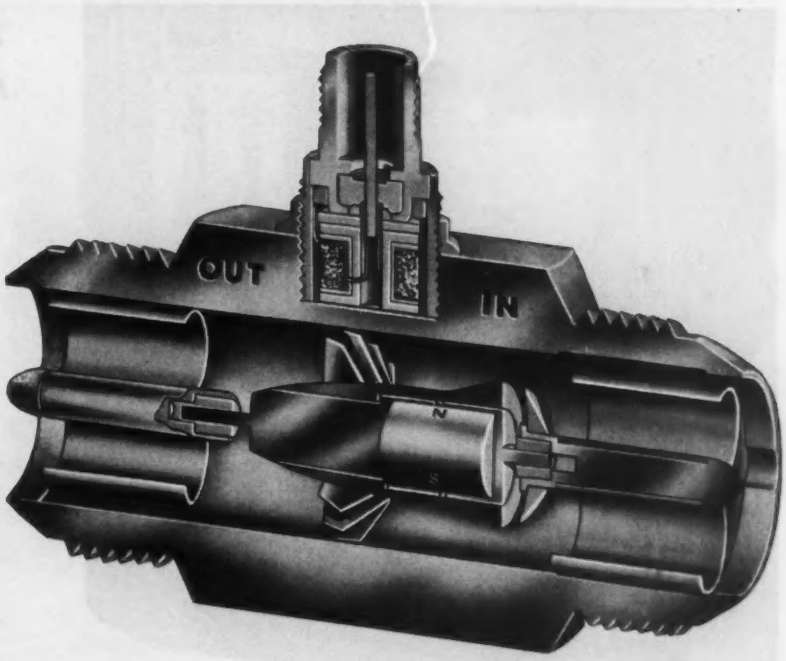
Wherever information on fluid flow is required,

the de Havilland POTTERMETER

sets new standards of accuracy and reliability







This new turbine-type flowmeter enables major advances to be made in the techniques of flow measurement and control. The de Havilland Pottermeter is the only flowmeter which offers all these features:

- **Accuracy to ± 0·1% or better on repetition work, ± 0·5% or better over a 20·1 range. Calibration remains constant for a variety of liquids over wide flow ranges.**
- Contains only one moving part — no thrust bearings — operates with a minimum of maintenance at high temperatures and pressures.
- No larger than the pipeline in which it is installed — may be mounted in any attitude.
- Can be supplied with indicating, recording and process control equipment — gives digital presentation of results.
- Can measure volumetric or mass flows.
- Models available to measure flows from 0·1 to 40,000 Imperial gallons per minute, at a wide range of operating pressures. Larger and smaller sizes made to order.
- Can measure flow of any liquid or gas, irrespective of its lubricating or non-lubricating properties, at temperatures ranging from -455°F to 1500°F.
- Manufactured as standard in stainless steel — can be made in any non-magnetic material.
- Rapid response rate permits transient flow studies.

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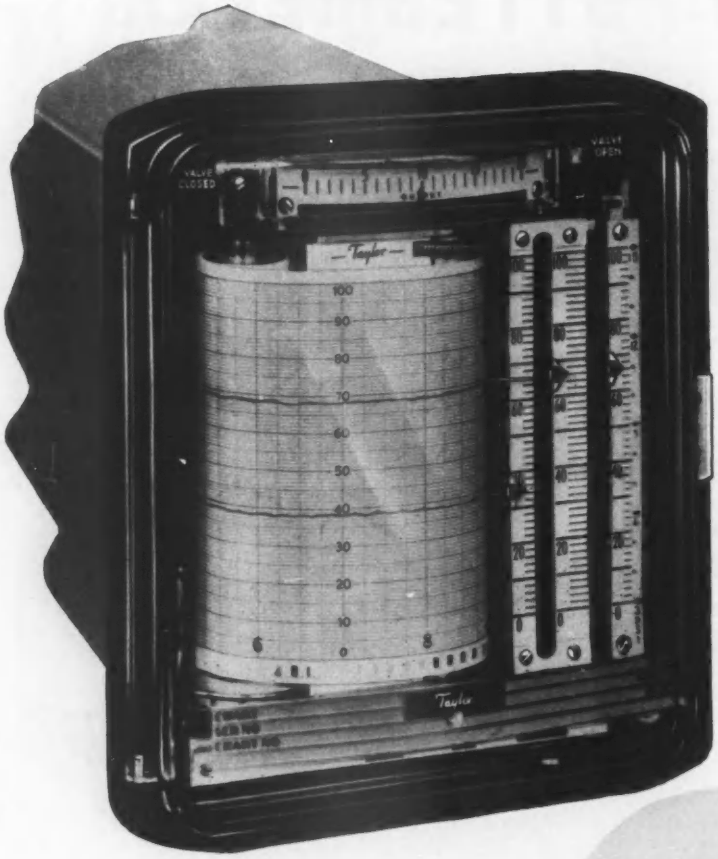

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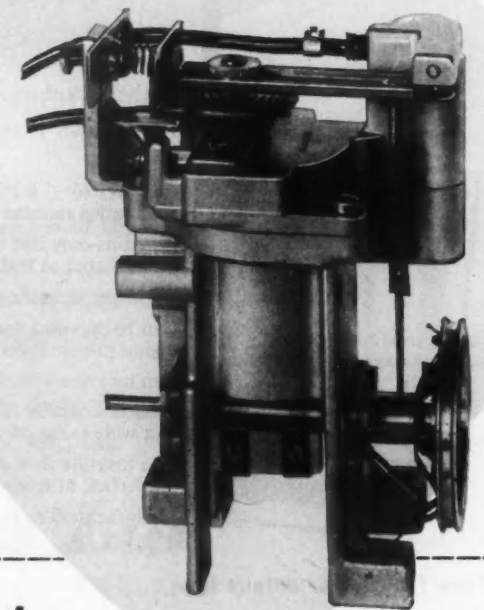
- Full 4″ 30-day chart
- 0.1% Threshold sensitivity
- Receives 3 variables
- Front control settings
- Integral alarms
- Complete cascade system
- Plug-in controller
- Dust and Splash proof door
- Totally enclosed case

"SERVOMATIC" MOTOR ASSURES LIFETIME ACCURACY
The 3-15 psi. Transmitter signal is received and amplified by individual force balance servo-mechanisms. Efficient spring feedback and powerful longstroke pneumatic motor give 150 times greater power than normally available for pen positioning. This means long, trouble free life!

0.1% THRESHOLD SENSITIVITY— A NEW STANDARD OF ACCURACY
Responsiveness to transmitter out-put is 0.1%; and because of the very small pneumatic displacement of the input capsule, the response is practically instantaneous. You see more minute process changes, enabling you to make optimum control settings to increase yield of specification product. All servos are identical and interchangeable. Servo-pen connection is by means of cable . . . no long, jointed, flimsy links or levers. Allows perfect linear conversion from rotary motion . . . repeatability is truly amazing.



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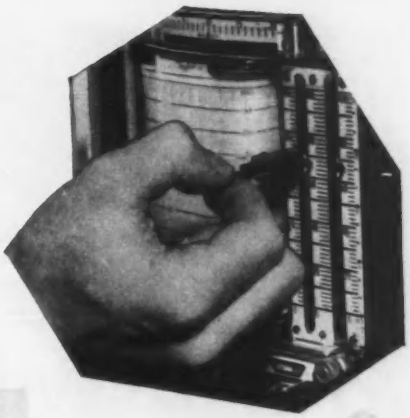
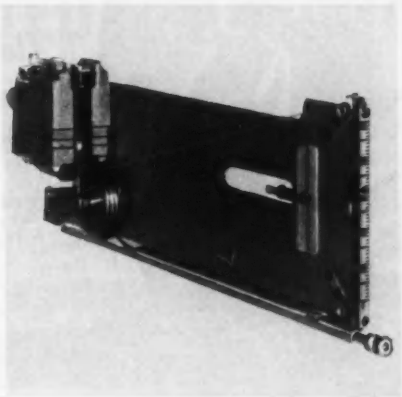


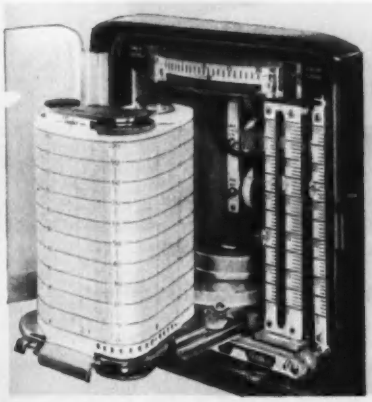
UNIQUE SET POINT TRANSMITTER

A big exclusive is the all-new "Set Point Transmitter". It allows continuous automatic control during recorder removal. The plug-in transmitter assembly itself may be removed, and the control valve sealed in operating position.



ELIMINATES MESSY PEN FILLING

3-month's ink supply comes factory sealed in disposable clear plastic cartridge — instantly replaceable. Rides on indicator arm. Powerful SERVOMATIC drive eliminates effects of friction and changing ink supply. As many as 3 variables which may be recorded or indicated — colour coded — each with its own direct-reading scale.



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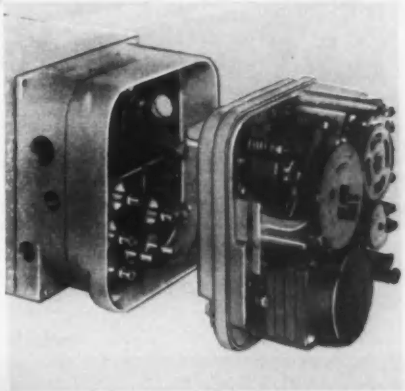
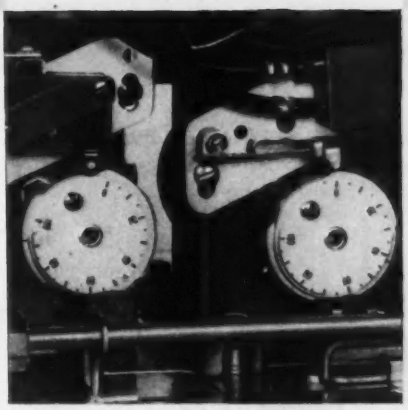
I.E.A. EXHIBITION

OLYMPIA 23-28 May 1960



BIG 4", 30-DAY CHART— DEPENDABLE ELECTRIC DRIVE

. . . same recording area as 12" circular chart . . . 3 hours of record visible . . . reads left to right like newspaper . . . variables plotted on straight vertical axis . . . has automatic rewind . . . convenient read-back feature . . . chart roll merely drops onto spindle . . . 3-way lock against slippage . . . chart swings aside for instrument settings while continuing to record . . . chart drive pulls out for simple reloading . . . automatic pen lifters.



EXPEDITES INSTALLATION

Sleeve with manifold can be installed during panel erection. The Recorder and Controller are simply plugged in at time of process start-up. This protects instruments against risks of damage.

OPTIONAL ALARMS

High-low set cams or 2-high or 2-low assemblies may be attached to SERVOMATIC MOTOR to actuate either electric or pneumatic alarms. Picture shows Microswitch on left, air valve on right.

Taylor Controls Limited

Hale End Road, Walthamstow, London, E.17. Telephone: Larkswood 5533

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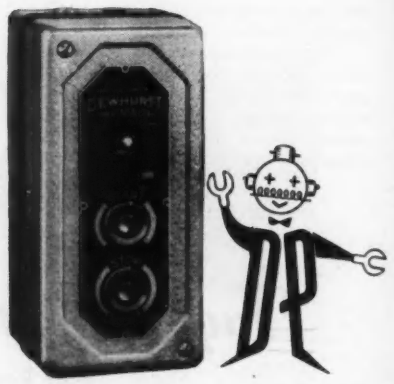
PAGE 3
FIRE DESTROYS LOCAL FACTORY
Electrical fault causes disastrous blaze
This afternoon, fire broke out in the new factory belonging to a leading local manufacturer. It is understood that, during the lunch time break, an electrical motor burnt out which c

...and it could happen to you!

In every factory where there are electric motors, there is the ever present danger of fire due to electrical faults such as single phasing and overloading — especially when starters are used that do not include the protection that is a basic part of the DUPAR TFK Starter.

Don't be tempted to economise on a starter that may be a few shillings cheaper, but does not include this positive protection.

THE DUPAR TFK STARTER INCLUDES THE SPECIAL ET PROTECTOR
— your insurance for complete safety of motor operation



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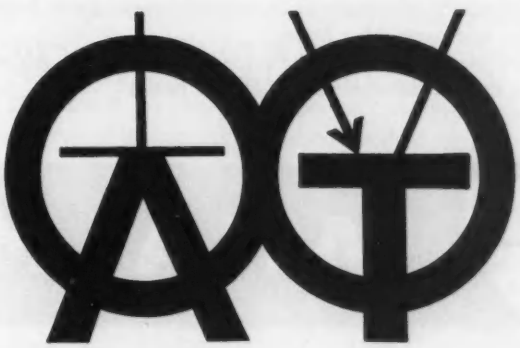

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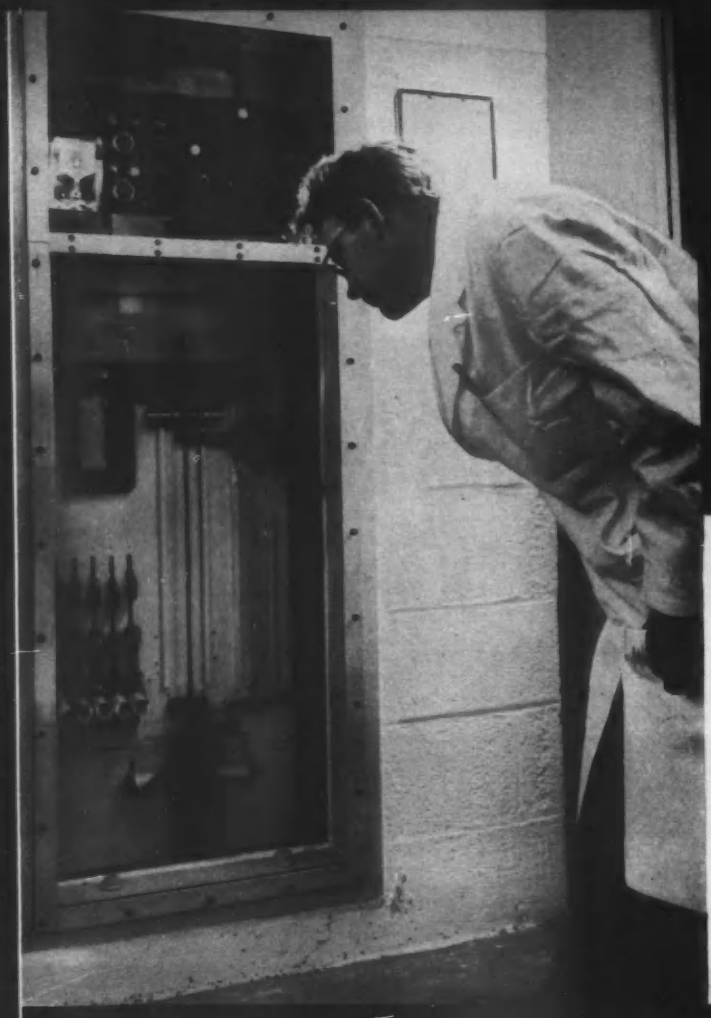

Are you using the latest developments in

AUTOMATIC CHEMICAL ANALYSIS

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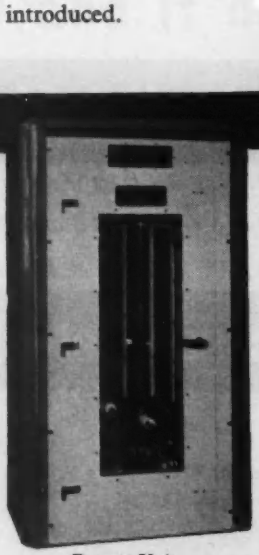
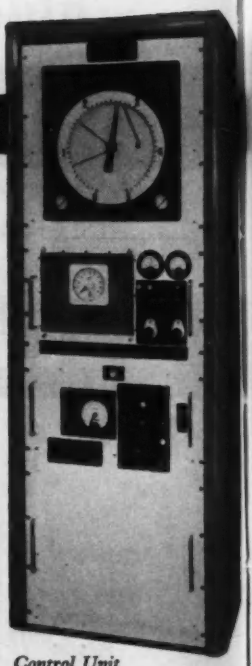
'ANALMATIC' equipment provides automatic chemical analysis with the highest standard of reliability and accuracy. It has been installed by leading companies for process and quality control. 'ANALMATIC' equipment cuts costs, frees trained chemists from routine work, improves efficiency in existing plant and enables new techniques and processes to be introduced.

'ANALMATIC' AUTO-TITRATION EQUIPMENT

The AUTO-TITRATOR is an outstanding example of the 'ANALMATIC' range. It can monitor a number of identical process streams by carrying out titrations to potentiometric, redox, 'dead-stop' or pH end points, or by colorimetric methods. Results of analyses can be provided as frequently as once every three minutes and can be fed direct to plant control systems. The AUTO-TITRATOR is designed to be easily adapted to suit the individual process. There are many applications in the production of heavy chemicals, petroleum products, pharmaceuticals, paint and paper and in brewing, water purification, and many other fields.
We shall be pleased to discuss the specific applications of 'ANALMATIC' equipment to meet the requirements of your process.



Burette Unit



Control Unit

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MAY 1960 VOL. 3 NO. 23 CONTROL

Points of novelty

'AUXILIARY', 'peripheral' or 'ancillary' equipment is usually so described in a rather dismissive tone, but not necessarily because it is thought to be unimportant: development may have been so thorough that the results have melted into the background of accepted things. 'Conventional' is another epithet frequently uttered in this well-meaning but dangerous way, suggesting that here is something we need no longer think about. It is good to have these kinds of plant or equipment paraded before us occasionally, to remind us that they do not just grow on trees. That is why exhibitions are useful even if, as so often, nothing new is shown. There have been times when, footsore and weary after a long spell among the stands, we have been bemused enough to doubt the purpose and value of it all, but afterwards we have usually been glad that we went. It is salutary to be jolted into re-awareness of forgotten essentials, although not so delightful as to discover novelty.

In the nature of things, most exhibits at a trade fair cannot be new, or at least not fundamentally so. Mark N is succeeded by Mark N+1, and there may be little in it but a new colour for the case. Still, deep-seated change does occur, slowly and steadily, and there are few better ways of following it than by seeing exhibitions. Schoolchildren are told how improving it is for them to perambulate through a museum. To the engineer, an exhibition is a museum which is devoted to the quick as well as to the dead, and its improving action should be so much the livelier.

The big show for control engineers this year is the third Instruments, Electronics and Automation Exhibition, which will be open at Olympia from 23 to 28 May. It has doubled its size for 1960, and this is to some extent a just indication of the industry's expansion. A small proportion of the display will come from foreign parts, and it might have been useful to make this proportion larger. The presence of foreign goods is desirable, if only to let British engineers take the measure of the competition. After all, one of the main functions of an exhibition is that of every market—to make possible the simultaneous comparison of many different wares. As readers will gather from the lengthy preview that we publish this month, the I.E.A. Exhibition will certainly do that.

We hasten to make clear that we do not decry the small show. Although an exhibition does tend to be valued according to its size, we know that there is occasionally more to be learned from a modest display. Such small exhibitions are sometimes disguised by being given other names, perhaps out of respect for their ampler relations. Last month, for example, the Society of Instrument Technology met at the Northampton C.A.T. to see an educational exhibition, though it was not given that frightening title in the advance notices: there it was called 'An Informal Evening on Novel Pneumatic Devices and Applications'. The meeting started at exactly the appointed time, with a pneumatic BANG! Nine speakers in succession then explained their devices with lantern slides and hardware, and an occasional gasp or shriek (from the hardware). A fair number of the devices were commercial goods, and we overheard one cynic remark that all this was 'darn good free publicity for some people'. Not fair comment, we thought, but it did show that there was a recognizable family-resemblance to commercial exhibitions. We ourselves did not see this resemblance as either too strong or deplorable, and we think that the meeting was a successful experiment.

Mr. Reginald Medlock, a CONTROL consultant and President of the S.I.T., was the last of the nine speakers. He showed his ingenious and instructive pneumatic plant simulator, which is a lattice made of elements possessing stiffness and inertia. The motions of the elements are viscously damped, and the apparatus simulates a plant with a transfer lag. It displays vividly and visually the phase relationships that may occur in such a system under different kinds of control. 'This device,' concluded Mr. Medlock after a diverting demonstration, 'has one point of novelty that the other eight didn't have: you can't buy it.'

That is the kind of thing one does not usually see at trade exhibitions.

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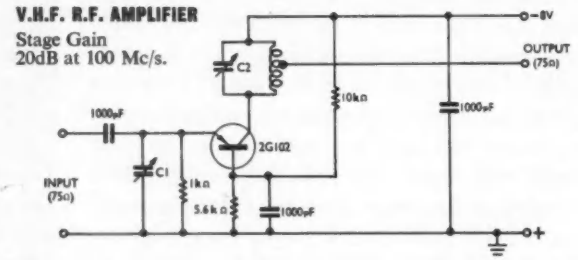

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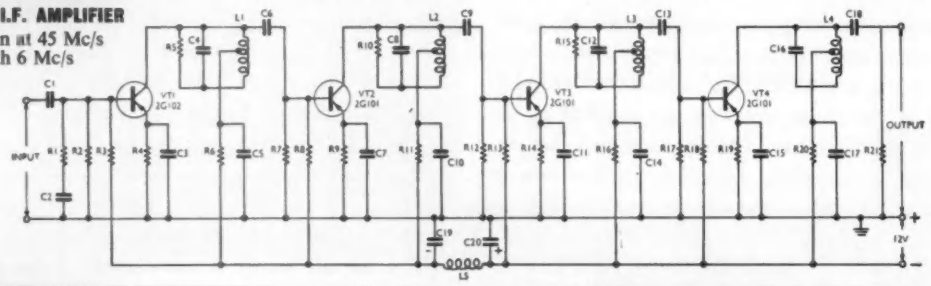
55dB Gain at 45 Mc/s
Bandwidth 6 Mc/s



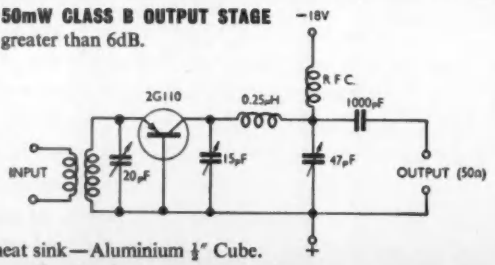
2G110

P_{tot}.....250mW
in free air at 25°C.

At 100 Mc/s.
P_{out}.....100mW min.
150mW typ.

P_G.....6dB

100 Mc/s 150mW CLASS B OUTPUT STAGE
Power gain greater than 6dB.



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LETTERS to the EDITOR

Teasing leader

SIR: I was interested and tantalized to see the reference in your leading article in your April number to lectures in this country by the Russian professor Ivahnenko.

Is it not rather naughty to whet readers' appetites like this, and not to tell them more about what was in the lectures, and whether copies are available (in English) in this country?

For my part, I would be very interested to see how much further the Russian professor has taken his work than, say, Tustin has done in Britain.

London, N.W.3. L. K. ROURKE

● *Sorry we could not work as quickly as we should have liked! You will find a review of Professor Ivahnenko's three lectures on pp. 163–5 of this issue, written specially for us by G. M. E. Williams of Northampton C.A.T.*—EDITOR

Justice about jargon

SIR: I was very angered to see the remarks by your 'Uncontrolled' in number 22 of your paper. It was not correct to accuse the German writer of xenophobia because he does not like English jargon. I am sure that he is just as strict with German words which are not exact and precise in their meaning. Does not this show rather that your 'Uncontrolled' is himself guilty of xenophobia with which he charges Dr. Roeper?

Düsseldorf WILLI RAUSCH

● *'Uncontrolled' tells us that he certainly did not intend to give such an impression, and that he was trying to be completely fair. On reading his article again we ourselves feel that he succeeded in this, though it may be that to a German mind the English phrasing conveys a different shade of implication. Being fair in our turn, we must admit that a similar distortion in 'Uncontrolled's' understanding of German may have led him astray also.*—EDITOR.

Living for computers

SIR: Mr. Brooker has not played quite fair with me in his reply to my letter in your April issue. It is both polite *and* realistic to assume that a human examination candidate has a brain, and the object of examining him is to test how good that brain is. There is no need to ask him for a diagram of his nervous system because (a) we—or our neurologists—already have a good idea of what it looks like, (b) it is irrelevant.

Mr. Brooker has also taken me to mean more than I have said when he chides me for fearing inferiority to machinery. He starts by saying that most of us live or work contentedly with our intellectual superiors, and then adds that many intellectually gifted people are happy with bosses less clever than they are. Therefore, his argument continues, we ought to yield sovereignty cheerfully to electronic computers: surely a non sequitur! How many wars have been fought to prevent domination by would-be herrenvolks! Why should we be more happy about enslavement to a computer than to any other organism? I have not denied the possibility of such enslavement, only deplored it.

South Kensington D. IDWAL JONES

Damn automation

SIR: In defiance of the remarks by 'Uncontrolled' in your April issue, I prefer 'automatise' to 'automate'. The apparent meaning of that horrible journalese word was very well illustrated by your artist on the same page. That cartoon ought surely to damn the word for all time.

Reading J. K. M. STUART

Shocking gears

SIR: The February and March numbers of CONTROL contained interesting articles on the choice of gear ratios for small servos as dependent on the working conditions. These small self-contained geared motors are very frequently used, and though the technical information about them sometimes specifies maximum output figures, these may not reach the man concerned with the system design. Such a man may be pardoned for assuming that a self-contained gear box is capable of carrying—at its output shaft—the maximum output of the motor of which it forms an integral part. This is often not so; and failures have resulted from not recognizing this fact.

The user of these gear head motors is well advised—in anything other than light instrument drives—to examine this point carefully. A very informative step is to consider the effect of an output load with a referred inertia equal to that of the motor. No calculations are needed. One has only to mount an armature and commutator equal in axial lengths to those of the driving motor but of $\sqrt{K}$ times their diameters, where K is the overall gear ratio. A sectional scale drawing of the gear box with such a flywheel on its output shaft will sometimes give one quite a nasty shock.

Although not always realistic, this elementary design exercise helps to give one a sense of proportion, particularly when factors such as limit stops and possible shock loads may be involved. In many of these gear heads the last stages of gearing are quite incapable of carrying the motor output, even when no shock loads are involved.

London, N.W.2 HUGH CLAUSEN

PUBLISHER'S COLUMN

Inhibitions and exhibitions

Freud is rather démodé *in these unshockable times, but our minds were irresistibly drawn to Freudian ideas when we saw a recent letter to the Editor. We are sure that the Editor and his correspondent will forgive us for a very mild breach of confidence—the temptation is tremendous and the sin trivial. We should like to invite the amateur psycho-analysts among* CONTROL *readers to devise an explanation for the entirely charming salutation that was written at the beginning of the letter. We ourselves have been able to think of several, and all of them are flattering. Just as it must delight the friends of a beauty queen who comes to be called 'Miss World', so did it delight us to see the Editor addressed as 'Dear Mr. Control'. What a wealth of implication is locked in that (Freudian?) slip!*

A 'Miss World' can show her enchantments with enviable ease. The task of an exhibitor at a trade fair is seldom so simple, as well we know, for we have been busy designing our stand for the I.E.A. this month. We hope that you will call on us there, and tell us what you think of the exhibition. 'Mr. Control', alas, cannot stay to welcome all comers all the time, but if we can help you in any way we surely will.

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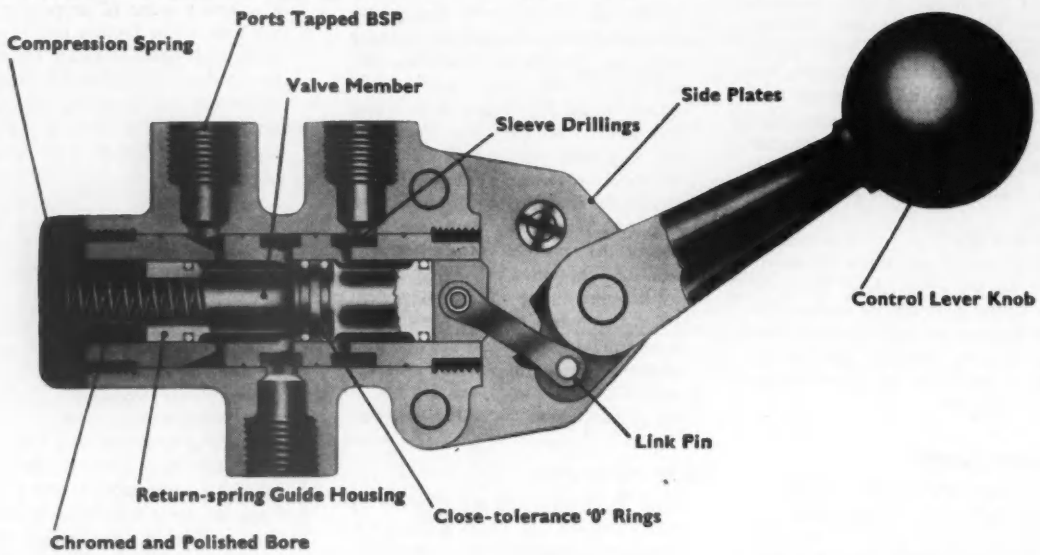

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VIEWPOINT

S. S. Carlisle, Assistant Director of the British Iron and Steel Research Association, sees a lamentable gap . . .

BETWEEN FEASIBILITY AND USE

Between what is obviously technically feasible in the automation of industrial processes and the measure of automation actually in routine use, there is a lamentable gap. For example, twenty years ago remote position-control was in general use in the Services for positioning gun turrets. Since then there have been major advances in the theory and design of such closed-loop control systems, in transducer elements for position monitoring, and in the appreciation by industry of the value of remote position-control. In steel mills, for example, it permits faster and more consistent adjustment of the screws of a rolling mill and ancillary guides to a specific position than is possible by hand-power control. Yet to-day there are only about ten mills in this country fitted with r.p.c. on mill screws—and not all are working satisfactorily. The mill managers want it (if it works), and equipment makers say there is no technical difficulty, and yet a research association still finds it necessary to do work on this problem. Pre-set sequential programme control of rolling-mill settings is of admitted value, and a few installations have been made, but operationally it is not yet satisfactory, often because of technical malfunction.

Studies have been made which show the feasibility and advantages of digital-computer planning of steelworks production and automatic scheduling of the operation of some processes; information-handling and data-reduction equipment is available which can be usefully applied in many parts of a steelworks. But what are the chances of a rapid and successful application of these technologies when there is stumbling over obvious and simple developments?

Different reasons for the gap between feasibility and use will be given by the four principal parties concerned, i.e. the steelmaker (or other industrialist) as the user, the plant builder, the instrument and control equipment manufacturer, and the allied research organizations. However, I think the most important need to-day is for a much closer co-ordination of the activities of these parties in the following respects.

Manufacturers of both processing plant and measurement and control equipment could learn more of the production logic and operational aspects of manufacturing processes, so that they can design properly integrated plant and control systems rather than just supplying components.

Control equipment manufacturers—some of whom have been progressive enough to install apparatus on trial in a works on a no-payment basis—should be prepared to back their initial enterprise with the effort to ensure that the system is so perfected that it goes into regular use. The user must learn how to use the apparatus; it will not work by itself, but if it is unreliable he should get the maker to put it right.

Plant builders might well associate themselves more intimately with instrument and control equipment manufacturers, giving the latter the necessary financial backing to do speculative development on apparatus vital to plant automation.

Furthermore, plant and control equipment makers might tackle more enthusiastically the development and application of new ideas evolved by research organizations. If the staff of the latter could have more confidence that their inventions would be enthusiastically pursued and applied in reasonable time, they might be more prepared to hand over their brain-children for engineering development at an earlier stage.

If this closer co-ordination of effort can be achieved, then I believe the British steel industry, for one, will be able to match that of any other country in its rapid and successful application of advanced automation. British equipment manufacturers in co-operation with research and development organizations are certainly competent to provide the technology.

S. S. Carlisle

From process control to data handling, Britain's greatest instrument show covers every facet of control and instrumentation

A Preview of the I.E.A. Exhibition

ABOUT 500 EXHIBITORS will provide a multiplicity of diverse equipments at the Third International Instruments, Electronics and Automation Exhibition, Monday 23 to Saturday 28 May, Olympia, London. The Exhibition has doubled in size since 1957, a rate of growth bound up with the accelerated development of automation in Britain. We consider that, to the control and instrumentation engineer, this may well prove to have been the most important technical exhibition of 1960.

MOST manufacturers of process control equipment seem to feature in this year's exhibition. A range of instruments to be shown by **Dewrance** (Stand M554) covers transmitting, recording, indicating, controlling and transducing, from a 115-V, 50-60 c/s power supply, and a 1 to 5 mA d.c. signal. The controllers and recorders of this miniature-design (Microsen) system employ printed wiring and have transistorized plug-in units.

There are one or two additions to the **Evershed & Vignoles** (Stand K458) range. A new three-term recorder-controller (transistorized) is in two units, inclusive of power sources, and gives a 4-in chart display in spite of its panel cut-out dimensions of 144 mm by 144 mm. Evershed will show pipe-type 'Dionic' cell conductivity control, a continuous device which does not need withdrawal of a sample in order to give a measured value input signal to the process controller. They will demonstrate the automatic mixing control of two substances from conductivity measurement.

Fielden Electronics (Stand C110) will exhibit their electronic system for control of a plant. This includes transmitter, indicators, recorders, controllers, electro-pneumatic converter, and positioners for pneumatic or electrically-operated valves. According to Fielden this gives d.c. transmission free from pick-up, low-energy (safe) transmitters, indication by moving-coil meters if necessary, three displays from a controller, flexibility for use in hybrid electronic/pneumatic systems, drift-free controllers and low maintenance, capital and installation costs.

A comprehensive range will also be shown by **Taylor Controls** (Stand D161). Their miniature series has many variations covering, ratio and computing relays, programme transmitter, manual loading stations, single recorder cascade station and 'Transverter.'

Hunt & Mitton (Stand H357) will display several Francel control instruments. The 'Stabilac' pneumatic recording controller for any process variable, has a proportional band calibrated as adjustable between 50% and 500%, although some 20% to infinity is said to be possible. Both integral and derivative time are adjustable from 0-50 min. They claim this controller to be of revolutionary design. The type BR pressure transmitter, which can be associated with the Stabilac controller, gives 3-15 lb/in² output signals. In effect, this is a simple proportional instrument. A Francel valve positioner can be associated with controller and transmitter in order to multiply the output signal for operation of a control valve. A Francel programme controller will also be shown. This will adjust the set point of a controller on a time basis so that process controls may be programmed.

The Automatic Control Division of **Constructors John Brown** (Stand H361) will show an electronic control panel as a unit in an auto-blending system. The blender shown is for two components but the system can blend up to ten liquids continuously. A transportable recorder for assessing the performance of industrial instruments and controllers will be demonstrated.

A sterilizer controller, to be shown by **Ericsson Telephones** (D153), controls automatic high-speed vacuum sterilizers by Alliotts of Nottingham. Any one or all three pre-set sterilizing processes, each controlled in four stages, are separately selected by push-buttons. Each stage may be varied in duration up to 24 min in 48 increment of 30 s.

An analogue computer for on-line process control—Anatrol—will be exhibited by **de Havilland Propellers** (Stand Q730). Reliability, flexibility and low cost have been achieved by programmed sequencing of a minimum of computing and storage elements. Anatrol is claimed to be particularly suitable for statistical evaluation of processes leading to optimization of controlled variables.

Recorders and controllers

Versatility and rationalization will be features of **George Kent's** stand (D159). There are several extensions to their Commander range of mechanical and electronic instruments, and in their Mark 3 range of electronic strip-chart recorders and recorder-controllers. The Mark 3 electronic instruments include a new model having a response of 1 s. for full-scale travel. The Mark 3 types on show are for single- or multi-point temperature measurement with optional air-operated control or transmission, and for electrolytic conductivity measurement. The latter version incorporates the new quadrature suppressor which eliminates any quadrature component at the amplifier input, improves sensitivity and accuracy, and prevents saturation.

Among working examples of the mechanically-operated Kent Mark 2 Multelec strip-chart recorder on view, will be a sensitive model for microvolt measurements, and a pH recorder with a miniature element immersed alternately in two solutions of different pH value. Commander electronic instruments will be demonstrated as a circular-chart recorder for use with a load cell and having four-position electric control, shown as an oxygen indicator-recorder with air-operated automatic control, and operated as a liquid-steel temperature measuring instrument connected to a thermocouple.

Various versions of their electronic recorder will be demonstrated by **Cambridge Instrument** (Stand F259). This forms part of equipment for measurements of temperature and radiation intensity, gas analysis, pH determination, and the measurement of electrical conductivity of solutions, calorific value of gases, and dissolved oxygen, hydrogen and residual hydrazine in feed water etc. As a self-balancing potentiometer, bridge, or current balance, the instrument will measure, record and, if required, control any quantity that can be converted into a suitable d.c. (sometimes a.c.) signal. The potentiometer will respond to a change in input of less than 1μV for the minimum range (1mV full scale) and the response time is shorter than 2 s. for full scale. The overall accuracy is better than 5μ V.

Metrix Instruments (Stand E219) will show the new Metrawatt transistorized controller. This employs h.f. oscillators whose coupling coils are on adjustable slides which can be set to the desired control values. A vane on the arm of the moving-coil meter enters the air gap of the oscillator coils when the pre-set position is reached. The oscillator circuits operate contactors to control the system.

A new d.c. potentiometric recorder with a 4-in. chart and multi-colour printing, will be shown by **A.E.I.** Instrumentation Division (Stand D152). A.E.I. will also show a new potentiometric indicator/controller, a continuously, self-balancing instrument whose 25-in scale can be traversed in 2 s.

A new modular Electronik design having four standard sub-assemblies will be featured by **Honeywell Controls** (Stand E200). This modular concept is applied to Honeywell's indicators, recorders and controllers. A constant voltage unit obviates periodic standardization and battery replacement. Honeywell will also introduce the new 'Electrik Tel-O-Set' miniature system comprising transmitters, recorders, controllers, transducers and final control elements. This is a two-wire d.c. transmission system.

Electronic Consotrol instruments by **Foxboro-Yoxall** (Stand E202) form a new range of measurement transmitters, recorders and controllers for flow, pressure, temperature, etc. These are solid-state designs using transistors and magnetic amplifiers. The universal controller is transistorized and has fully-adjustable settings—proportional band, integral and derivative; the flow controller (magnetic amplifier) has controller settings fixed at optimum values.

Speedomax G and H recorders and controllers for temperature, millivoltage, conductivity, pH, redox, etc., will be shown by **Integra, Leeds & Northrup** (Stand D163). The type H is small (12 in. by 11 in. by 11 in.) and less costly, has plug-in components and all moving parts operate from a common shaft driven by the positive worm-gear of a high-speed balancing motor. Performance will be demonstrated for position, duration, and current-adjusting control. Various **Speedomax** instruments will demonstrate single- and multi-point indication and recording.

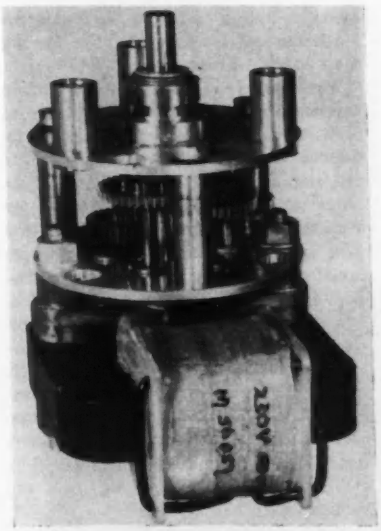
Among the many instruments exhibited by **B & K Laboratories** (Stand E203) will be the Oscillomink 230B, an ink recording instrument capable of recording up to 1000 c/s with a sensitivity variable from 0·2 mm/mV to 4 mm/mV. The direct writing system is based on the use of a fine jet of ink which is impelled at high speed from a nozzle in the centre of the galvanometer. The resonant frequency is about 650 c/s. Paper speeds are 5, 10, 20, 50, 100 and 200 mm/s. and the accuracy is better than 1%.

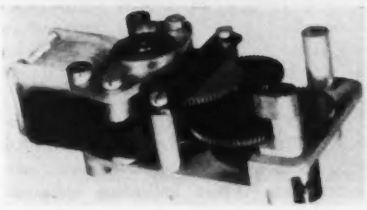
A five-channel high-frequency recording system will be demonstrated by **Kelvin Hughes** (Stand F257), a simulator providing the five variable-impedance pick-ups. This is a Teledeltos paper recorder and there are six paper-speeds, 0·5, 1, 2, 4, 8 and 16 cm/s. With 9·2-cm pens this is $\pm$ 2 cm per channel with a frequency response uniform within 10% from 0-60 c/s. Kelvin Hughes will also show an R.A.E.-designed four-channel dynamic strain recording equipment.

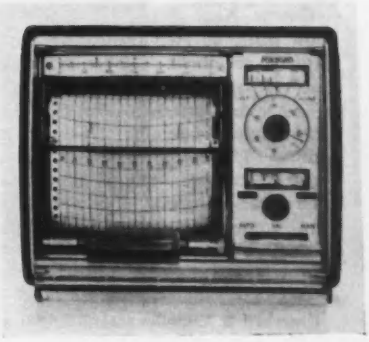
F. C. Robinson & Partners (Stand B51) will exhibit the Autovisor operation recorder. This provides an automatic and continuous record on one chart of the periods of operation of from one to twenty processes or machines. These recorders are available in single-pen strip-chart and disk models, and 2, 6, 10, 15 and 20-pen strip-chart models.

Temperature control

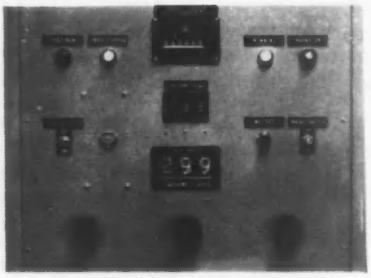
The large number of exhibits which in one form or another are concerned with temperature, drives home the importance of this field to the control

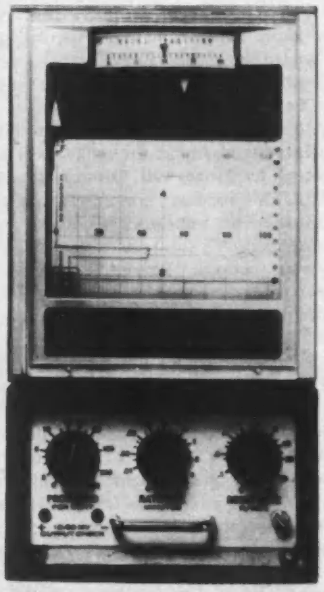






Left: Oliver Pell motor with circular gear box and, bottom left, with rectangular gear box
Below: Foxboro's electronic (solid state) Consotrol recorder-controller





Above : Honeywell Control's miniature recorder-controller in the new Electrik Tel-O-Set range
Top left : The Post Office will feature the Automatic Telex system. Here an operator dials a distant subscriber
Bottom left : Gilbarco remote pre-setting control unit for Brodie-Kent fuel flowmeter

engineer. **Cambridge Instrument** (Stand F259) will demonstrate their multi-point electronic recorder-controller regulating the temperature of six miniature furnaces. Based on a standard recorder, this instrument employs a mechanical differential system operating six cams, each of which can be adjusted to provide independent control settings. Cambridge will also show a 12-point electronic recorder (a self-balancing d.c. bridge) with resistance thermometers, a single-point electronic recorder operating from a radiation thermopile, a six-point high-speed electronic recorder operating from fine-wire thermocouples and measuring local air temperatures, and their Minican pocket-size temperature recorder for use in confined spaces.

George Kent (Stand D159) will also show many of their controllers and recorders—see above—for use in temperature regulation. A liquid-steel element will be demonstrated connected to a thermocouple operated from a heat source. The Kent mechanical 'energy regulator' enables manual proportional control, or air-operated two- or three-term control to be added to plant originally fitted with on/off control only —furnace stoker-speed control, for example.

Evershed & Vignoles (Stand K458) will show a new transmitting resistance thermometer which provides a signal for indication or recording or for use by their Mark 4 process controller.

The Bikini range of transistorized temperature instruments, which operate with resistance bulbs, will be shown by **Fielden Electronics** (Stand C110). Their precision controller is sealed and gives on/off action, and their indicator is also a sealed unit; the recorder can be fitted with control contacts or give proportional control. They will show d.c. potentiometer recorders with control facilities, for use from thermocouples. Fielden will also exhibit a simple multi-point indicator, for use with thermocouples, which has no electronic valves, slide wire, servo motor, etc.—the cost for 24 points can be less than £5 a point. A four-point transistorized thermometer having a 10-in diameter chart and operating from resistance bulbs will be shown.

A new instrument for **Taylor Controls** (Stand D161) is the Sensaire temperature transmitter. This converts temperature measured by a mercury-filled system into a proportional 3-15 lb/in^2 air output pressure.

Foster Instrument (Stand C111) celebrate fifty years in temperature control this year, and will show several new instruments. Their indicating temperature controllers are available as electro-mechanical or photo-transistor designs and can give on/off, two- or three-step control. The photo-transistor model also provides attenuating and saturable reactor control. Programme control is available. In Fosters' new self-setting Teloscale, the visible portion of the scale is automatically re-set in accordance with the temperature being measured. Their non-indicating resistance controller is an inexpensive device which incorporates a deviation indicator giving the temperature deviation from the control point. They will also exhibit a quick-reading immersion pyrometer for molten glass, a range of optical and radiation pyrometers, and deflectional and self-balancing potentiometric instruments.

Ether and **Electro Methods** (Stand E205) will feature a complete range of temperature measuring and control instruments including millivolt and potentiometric types. Among their newer products are Xactrol potentiometer recording controllers and an improved Transitrol temperature controller.

A time proportioning controller, to be shown by **Sifam Electrical Instrument** (Stand S855), has been designed for accurate control. Here the ratio of 'off' to 'on' time is continuously varied in accordance with the instantaneous temperature. Sifam's Pyromaxim electronic on/off controller, a thermocouple instrument, is accurate to 1% f.s.d. and its response is said to be better than 0·25%.

James Gordon (Stand D155) will feature automatic combustion control, pneumatic and electronic, for boilers and furnaces, temperature control for superheated steam and so forth. **Industrial Pyrometer** (Stand L509) will feature a great deal of industrial automatic temperature control equipment, including manual gas governors, safety controllers, Pyrostat control, indicating pyrometer controllers, multi-point pyrometers etc.

A solid-state temperature controller by **Phoenix Telephone and Electric** (Stand R817) is for furnace control from a resistance thermometer. A transistor pre-amplifier feeds a magnetic amplifier to give a 25-watt output proportional to temperature error. This controls a saturable reactor in the furnace power line. They will show a magnetic amplifier for control from a thermocouple and an electronic thermometer.

Among **West Instrument's** (Stand H354) range will be a multi-point scanner and a new stepless controller. The scanner, which can monitor continuously the temperatures of up to twelve thermocouple or resistance-bulb positions, can be arranged to sound an alarm and/or shut down equipment. The stepless controller has a power range from 3% to 90% of full power from a saturable reactor; it can be operated manually.

Temperature ancillaries

Measurement of the temperature gradient of an electric fire, using thermocouples welded on to the element, will be demonstrated by **Ericsson Telephones** (Stand D153). A differential input amplifier will be used to eliminate the common mode of the 250 V, 50 c/s, heater supply between thermocouple and earth.

Plessey (Stand M558) will demonstrate a sensitive temperature controller, originally developed to de-ice aircraft windscreens. As demonstrated, this will employ a photo-transistor in the control channel. Breaking a light beam will bring in an 'overheat' channel arranged to protect force-cooled equipment from the effects of blower failure. On the same stand, **Hagan Controls** will show a thermostat for the pneumatic control of temperatures (up to 1400°F) in large ducts and gas-turbine exhausts.

Both **Ekco Electronics** (Stand E208) and **Murphy Radio** (Stand E209) will exhibit thermocouple trip amplifiers for the operation of alarms and controls if pre-set levels are exceeded.

Marconi Instruments (Stand D157) will demonstrate a temperature scanning system for continuous monitoring of a large number of thermocouples.

Many exhibitors will exhibit thermometers of one form or another. **Wayne Kerr** (Stand E217) have an electronic thermometer covering 0-50°C and 50-100°C to 1°C accuracy. **British Rototherm** (Stand Q729) will show a comprehensive range of dial thermometers (bi-metal, mercury-in-steel vapour pressure), recorders and controllers. **Negretti & Zambra** (Stand C105) will also have a wide range of instruments and controllers of this nature, as will **Coley Thermometers** (Stand Q708F) and **G. H. Zeal** (Stand L504). The latter will demonstrate electric contact thermometers carrying out temperature control of water and air. **B.I.C.C.** (Stand R813) will emphasize their mineral-insulated thermocouples, including two flexible rope-like assemblies. **Engelhard Industries'** Baker Platinum Division (Stand N606) will show three fairly recent developments: an integral sheath thermocouple, Fibro thermoelement platinum, and thermocouples for temperatures above 1600°C.

Graviner (Stand R827) will show a range by Fenwal Inc., U.S.A., including an indicator-controller, thermistor controller, general purpose and high temperature units and miniature thermostats. They will also show temperature control switches and fire detectors. Fire prevention by nuclear detection will be demonstrated by **Minerva** (Stand G309).

Flow measurement and control

A precision flowmeter, the Pottermeter, which has an hydraulically-positioned 'bearing-less' rotor will be demonstrated by **de Havilland Propellers** (Stand Q730). **Meterflow,** who share **S.E. Laboratories'** stand (D167), will show their flowmeters which similarly attempt to overcome friction by a thrust-relieving technique. S.E.L. will show a variety of solenoid, reducing and other valves.

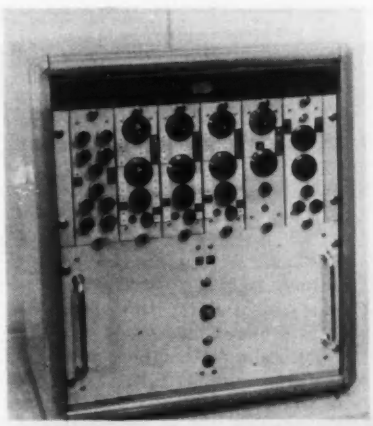
On the **Hawker Siddeley Group** stand (L508), a combined **Brush Electrical, Armstrong Whitworth Aircraft, Armstrong Whitworth Equipment** and **A. V. Roe** exhibit having the theme, control systems for automation. A.W.E. will show flowmeters as part of a data-acquisition section.

Alto Instruments (Stand R816) will exhibit their induction flowmeter in which the liquid acts as a moving conductor in a magnetic field, so generating an e.m.f. proportional to flow velocity. Turbine flowmeters will be exhibited by **Leeds Meter** (Stand J401) together with rotary, displacement and helix meters; fuel flowmeters by **Negretti & Zambra** (Stand C105); magnetic flowmeters, indicators and accessories by **Fischer & Porter** (Stand A10), and industrial flowmeters and integrators by **Firth Cleveland** (Stand H353) and **Metrix Instruments** (Stand E219). **Rotameter** will have a comprehensive display of fluid measurement and control apparatus on Stand E210.

The **Warren Spring Laboratory** of D.S.I.R. (Stand E214) will show a radioactive Rotameter which enables the position of the float to be detected when measuring low flows at high pressures.

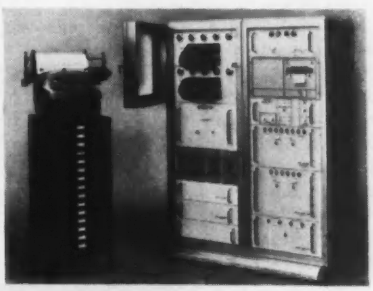
Differential converter-transmitters for flow and liquid level, etc., will be shown by **Honeywell Controls** (Stand E200), and **A.E.I.** (Stand D152) will show a pneumatic flow-recorder having a 12-in chart and employing the Barton differential pressure unit. **Walker, Crosweller** (Stand Q700) will exhibit flow recorders for gas, steam, water, etc., and demonstrate the V-notch liquid flow recorder. **George Kent's** (Stand D159) Commander range will include a mercurial flow indicator, a bellows-operated mercury-less flow recorder, and a float-operated instrument for measuring open-channel flow. Kent will also show pipe-line flowmeters, aircraft fuel meters, etc.

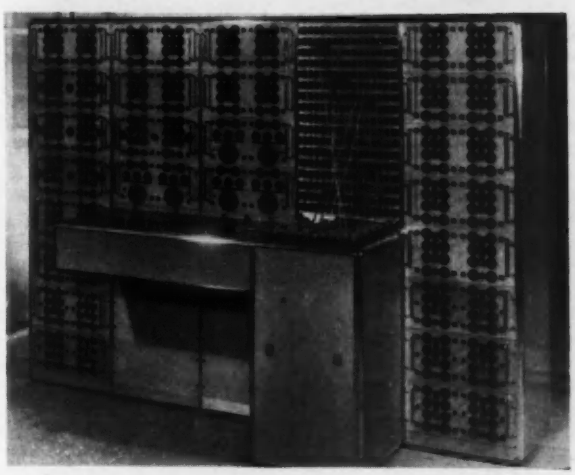
Brodie-Kent positive displacement meters and ancillaries and the remote control equipment for handling petroleum products will be shown by **Gilbarco** (Stand G302).



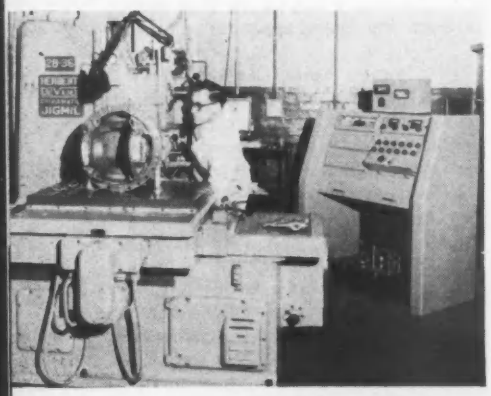
Left: Bruce Peebles' small analogue computer is priced at £310

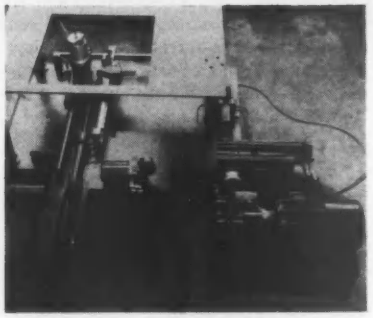
Below: Blackburn Electronics' data logger





Tana, a transformer analogue network analyser by F. C. Robinson and Partners, will solve simultaneous equations with complex coefficients in power system studies





Top left: Plessey machine tool control system coupled to a Herbert de Vlieg Jigmil

Above: Teledictor machine tool control console

Bottom left: This prototype model of a copy miller by Sperry Gyroscope is constructed from standard Sperry servo components

A photo-transistor flow alarm working with a direct-reading flowmeter will be demonstrated by **G. A. Platon** (Stand G317), together with a wide range of self-acting flow controllers.

Automatic liquid dispensing will be demonstrated by **Measurement Ltd.** (Stand E221), a variable-stroke pump delivering oil to a series meter and a rotary-piston meter which can operate counters or a rate-of-flow indicator. Liquid handling with automatic batch control will also be the theme of the **Tylors of London** stand (A1), their range of positive displacement meters having been extended.

Control valves

Very many firms will show flow regulators and valves of one form or another. **Hagan Controls** (Plessey Stand M558) have an oil control valve for the precise feeding of liquid fuel to burners; **Grundy & Partners** (Stand S868), glass solenoid valves for corrosive liquids and gases; **Crosby Valve** (Stand F253), a range of control valves, including a sectioned 16-in double-seated type in operation, butterfly valves, etc.; **Dewrance** (Stand M554), solenoid valves and valve actuators; **Hunt & Mitton** (Stand H375), process control valves and actuators; **Audley Engineering** (Stand K454), control valves for pressures up to 6000 lb/in^2, and a small ('Wee Willie') valve for extremely small flows at up to 50,000 lb/in^3; **Alexander Controls** (Stand G318), solenoid, air-operated and motorized valves; **James Gordon** (Stand D155), automatic combustion control valves, etc.

Data handling and computation

Digital and analogue computing equipment, together with various data acquisition, transmission and processing ancillaries, will be much in evidence. Among exhibitors of analogue computing and simulation equipment will be **English Electric** (Stand E215), with their Lace Mk II (lent by Huddersfield Technical College), and a nuclear reactor simulator for operator training; **E.M.I. Electronics** (Stand D166) with the Emiac II analogue computer which will be demonstrated in a process control application; **General Precision Systems** (Stand M560) with a nuclear reactor simulator and a new range of d.c. analogue computer components; **Feedback** (Servomex Controls' Stand F255), with a d.c. amplifier, a square wave unit, and an analogue and simulator teaching unit; **Short Bros. & Harland** (Stand M557), with their new Simlac Minor small general-purpose machine (which has 32 amplifiers and 100 passive elements), an eighteen-amplifier machine and various computing units; **F. C. Robinson** (Stand B5), with their transformer analogue network analyzer which solves simultaneous equations with complex co-efficients, in power system studies; **Bruce Peebles** (Stand R802), with analogue computing units; **A.E.I.** (Stand E213) with the type 955 analogue computer, and (Stand D152) a plant simulator for demonstrating the effects of introducing various functions into a pneumatic control system, and a multiplier employing the Hall effect in semiconductors; **de Havilland Propellers'** (Stand Q730) analogue computer, Anatrol is for on-line process control.

Kelvin Hughes (Stand F257) will exhibit their automatic boiler control simulator, a device for training and demonstration of their boiler controls. This will demonstrate the speed at which an automatic system establishes optimum conditions.

Ferranti (Stand N604) will exhibit the Sirius and Argus transistorized digital computers. Sirius, a desk-sized machine, costs £17,500, while the Argus digital computer, which is for the real-time control of industrial processes, may vary in price between £30,000 and £70,000 depending on the size of the installation. **E.M.I.** (Stand D166) will show ancillary equipment used in their Emidec 1100 and 2400 digital computers, and illustrate Fred—figure reading electronic device—a high-speed cheque sorter and computer-input mechanism.

A random number generator will be demonstrated by **Phoenix Telephone** on Stand R817.

Turning to peripheral and ancillary equipment: **Lintronic** (Stand B55) will show a system for converting analogue simulator outputs into digital form for a computer or X-Y plotter, a digital recorder of transient voltage signals for linkage with a computer, and a ten-channel high-speed (up to 10 kc/s) low-level signals commutator, or switch, for data handling.

Plessey (Stand M558) will show Ferramic memory matrices and stores, including cores for fast switching, and **Sperry** (Stand C101), magnetic storage drums in telephone applications, and a new drum, type C, of great storage capacity.

Much tape equipment will be exhibited. **Ultra Electronics** (Stand R820) will show a magnetic read/write head for digital computer input/output, and a transistorized punched-tape merger for combining the data on two tapes in a single tape. Among **B. & K. Laboratories'** (Stand E203) magnetic tape devices will be a high-speed digital magnetic tape handler capable of forward/reverse cycling at 120 in./sec. **Epsylon** (Stand D167) will show a high-speed unit for digital computers.

A high-speed X-Y recorder will be shown by **Ekco Electronics** (Stand E208), and a Cartesian co-ordinate graph plotter by **Teledictor** (Stand C114).

The **Post Office** (Stand R823) will also have an exhibit of data-handling interest. This will be mainly concerned with automatic telephone exchanges (automatic

switching), the Telex service, and data transmission via punched tape.

Data logging

Several firms will exhibit data loggers and scanners. These include **Blackburn Electronics** (Stand Q710); **Kelvin Hughes** (Stand F257), whose data handling system can scan and log any number of process variables to 0·1% accuracy of the reading; **Marconi Instruments** (Stand D157), with a burst slug detection system and temperature scanning (600 thermocouples at 5 per second) equipment for Hinkley Point nuclear power station; **Hagan Controls** (Plessey Stand M558), with the Kybernetes automatic data scanning and computing system; **Hawker Siddeley** (Stand L508); **de Havilland Propellers** (Stand Q730) with Dame—data acquisition and monitoring equipment; **A.E.I.** (Stand D152) with a nuclear burst-cartridge detection computer and a 16-point data logger; **Ericsson Telephones** (Stand D153), whose data handling equipment includes a variety of devices for incorporation in data logging systems; **English Electric** (Stand E215), whose multi-point scanner incorporates the new Datapacs—basic logical elements; and **Cambridge Instrument** (Stand F259) whose in-line scanning recorder will select and scan from 20 up to 400 points.

Analogue-digital conversion

Various methods of converting analogue data into digital form will be displayed. **Ferranti** (Stand N604) will exhibit precision wire-wound potentiometers —one, Europe's smallest—for analogue conversion from mechanical rotation to an electrical signal, and **Ketay** (Plessey Stand M558), a shaft-position encoder which translates analogue input into digital electrical form. **Colvern** (Stand Q723) will demonstrate shaft digitizers giving high resolution analogue-digital conversion by means of coarse/fine techniques. Single coders are used having 21,600 divisions over a single shaft revolution, and the numerical output is displayed in degrees and minutes. **Murphy Radio** (Stand E209) will exhibit their frequency-analogue converter which converts signals in the 1–100 c/s range to proportional analogue output signals which are adjustable from 10–30 mV, f.s.d. The latter is intended for process control.

Racal (Stand F260) will show a transistorized voltage-frequency converter, for converting a counter into a digital voltmeter, and **Marconi Instruments** (Stand D159) their digitizer, a transistorized analogue-digital converter for feeding indicators, recorders or processing equipment the value of an applied d.c. potential from 0–0·999 volt.

An industrial analogue-digital converter by **Evershed** (Stand K458) embodies an encoder transmitter and is suitable for industrial telemetry.

Machine control

Several machine-tool controls will be on view. **Ekco Electronics** (Stand E208) will show a punched-card storage system fitted to an Elgar jig borer. This provides automatic co-ordinate setting; it can re-set a 10 turn/in leadscrew to ± 1/500 of a turn and can control up to 1000 turns. **Plessey** (Stand M558) will illustrate the system they designed in collaboration with Alfred Herbert. The latter is a punched-tape programmed system for the operation of tools in three dimensions.

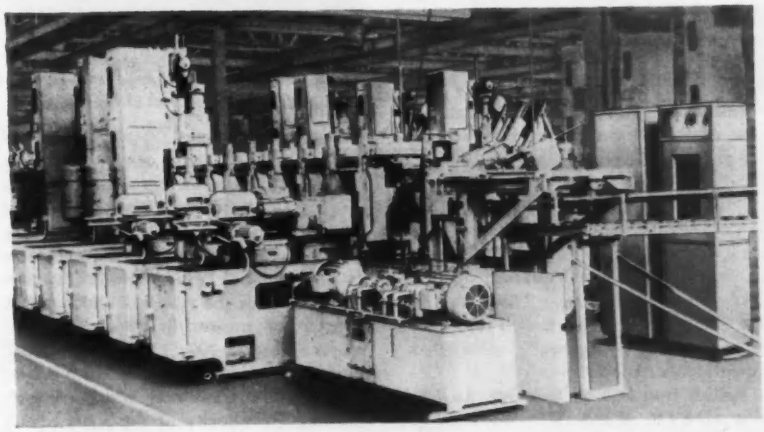
Teledictor (Stand C114) machine tool control systems are for the manufacture and inspection of component parts. The range comprises static positioning equipment for jig boring or drilling to an accuracy of 0·002 in. in 10 in., and control consoles with integral programmes for the manufacture or inspection of parts having linear or linear/circular contours. Manual or punched-card control is available. The consoles may control copy milling to an adjustable scale factor.

Sperry Gyroscope (Stand C101) will demonstrate a 360° copy milling system, for milling to templates, within 0·0002 in. at a feed rate of 20 in/min. Fitted with hydraulic jacks for tool movement, the system is built up from standard Sperry servo components.

Static switching built up on the 'NOR' logic system will be demonstrated by **A.E.I.** (Stand E213) controlling the operation of a—diagrammatic—capstan lathe. **G.E.C.** (Stand E211) will show a sequence control unit which they have used to control an injection-moulding machine. This provides timing and triggering for many simultaneous and successive operations and employs logic boards, transistorized printed circuits and cold cathode valves. G.E.C. will also demonstrate a micrometer with decimal read-out, which consists of four digitizers linked together to give a micrometer reading in multiples of 0·0001 in.

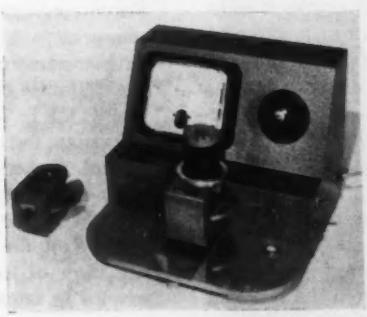
Hivac (A.T. & E. Stand F261) will demonstrate a working model of Access —the Austin cold cathode electronic switching system, which Austin and Hivac have patented jointly and which the **Donovan Electrical Co.** are manufacturing. Originally developed for the fully-automatic control of transfer machines, Access is now being applied to a wider range of production units.

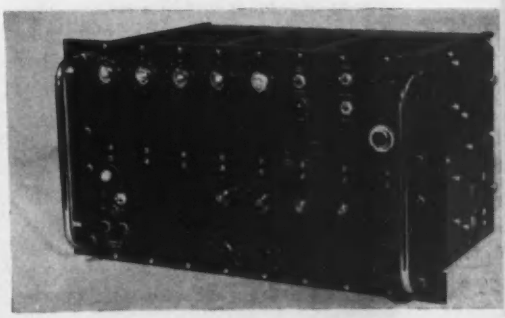
Ferranti (Stand N604) will show their co-ordinate inspection machine, with

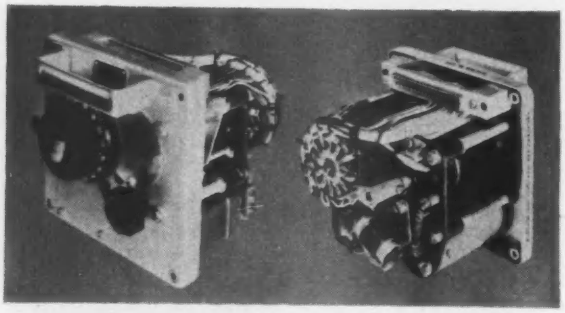


The Austin cold cathode electronic switching system—Access—controlling a transfer machine. A joint Austin-Hivac Development. Access is manufactured by Donovan Electrical.

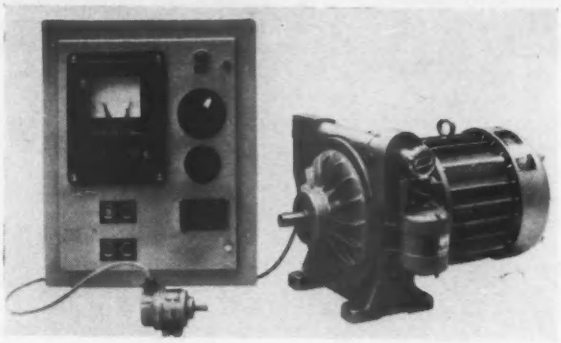
Bottom left: E.M.O. Instrumentation's synchro torque testing machine for measuring the overall friction and electrical torque of assembled synchros. Bottom right: This tachometer by Ericsson Telephones can measure up to 1,200,000 rev/min.







Plessey's remotely controlled auto-tuner can rotate and lock a shaft to an accuracy of six minutes of arc



A Kopp variable-speed gear may be controlled to provide a constant output with Allspeeds' speed corrector unit

which a probe can be placed at any point on a machined part. Sensing units are fitted to the *x* and *y* axes of the machine and motion along either axis is determined by a Moiré fringe pattern technique. The position of the probe is given to an accuracy of 0·001 in. Ferranti will also exhibit a transistorized bi-directional counter developed for use with Moiré fringe measuring systems.

The hydraulic control of rapid traverse and feed movements in machine tools is the duty of flow controller feed units which **Wilmot Breeden** will exhibit on Stand Q708D. These can be fitted with a remote-controlled feed regulator, operated by hydraulic, solenoid or potentiometer control.

British Iron & Steel Research Association (D.S.I.R. Stand E214) have developed a new method of measuring small reductions in strip steel thickness—the thinner the strip, the faster does it leave the rollers. Strip speed before and after rolling is compared photo-electrically and thickness reduction thus deduced.

Tachometry

Ericsson Telephones (Stand D153) will exhibit a rate error sensor which is basically a transistorized tachometer incorporating a device for sensing that the rate lies within selected limits. Relay-operated contacts permit this to control the rate within limits. Ericsson will also show the type 144A tachometer capable of measuring up to 1,200,000 rev/min from a 100 c/s reference source. Ericsson's Rotapulse is a shaft-driven photo-electric transducer which converts the angular velocity of the shaft into a number of pulses per revolution.

An electronic tachometer, or frequency meter, by **Airmec** (Stand D162) is transistorized, and **Erie Resistor's** (Stand D169) frequency counter and digital tachometer—an events-per-minute-time counter—is similar.

Murphy Radio (Stand E209) will exhibit a precision industrial tachometer comprising a photo-electric tacho-generator, an electronic counter and a digital display unit.

Ketay (Plessey Stand M558) will show a temperature-compensated precision integrating tachometer, among their servo-motors, and **Vactric** (Stand M555) will include tacho-generators among their servo-components.

Control of rotary speed

A new device on **Allspeeds'** stand (R810) is a speed corrector unit for use with their Kopp variable speed gears. This will automatically adjust a varying speed to provide a constant linear or rotary speed.

A.E.I. (Stand E213) will demonstrate a 1 h.p. motor control unit using silicon controlled rectifiers, and also a magnetic amplifier motor speed control for use with a 12-section knitting machine. **Westinghouse** (Stand Q707) will demonstrate their high power silicon Trinistor switches and power silicon transistors in motor control, and **Brush** (Hawker Siddeley Stand L508), motor speed control by controlled rectifiers. **Zenith Electrical** (Stand F272) and **Engelhard Hanovia** (Stand N606) will also exhibit speed control devices.

A servo-operated speed controller, working on the velodyne principle, will be exhibited by **Servomex Controls** (Stand F255). This provides 0·5 b.h.p., has a speed range of 0–7500 rev/min, forward or reverse, and is stable to ± 2 rev/min per hour on constant load.

Plessey (Stand M558) will exhibit their auto-tuner, a motor driven remotely-controlled device for rotating and locking a shaft to an accuracy of six minutes of arc at any one of twelve positions within 330°.

Electronics and control

It is, of course, quite impossible to do more than touch upon an almost random selection of the very large number of exhibits at the Show, in this preview. It is hoped, however, that some idea of the Exhibition's importance to the control engineer has been given.

Process control equipment has been stressed in this preview. This results from the very large number of old-established instrument firms who are participating in the Show and, indeed, are able to stand happily alongside the newer recruits to the industry who, in the main, have an electronics background.

The ever-growing interest of the electronics industry in instrumentation and control is apparent from the fact that the Electronic Forum for Industry is to hold a three-day conference (May 24–26) on ' User Experience of Electronics in Industry ' at Olympia, concurrently with the I.E.A. The Forum consists of the nine manufacturing associations concerned with electronics, and that they should consider an instrument exhibition to be a suitable vehicle for their first full-scale conference is surely a pointer to the future. The E.F.F.I. conference will cover electronics in data processing, factory applications and in instrumentation and control. Tickets are available at £1 11s. 6d. per session from The Electronic Engineering Association, 11 Green Street, London, W.1.

All in all, the I.E.A. should prove to be the most important show of its type ever held. You are strongly recommended to attend—and do visit CONTROL on Stand A8.

An eye-witness story to interest many CONTROL *readers, and not merely those concerned with guided weapons. The writer was the only journalist to see and photograph the first underwater firing of the Polaris missile*

POLARIS FIRED

by BASIL CLARKE
Rowse Muir Publications Ltd.

(Top) The U.S.S. 'George Washington', with sixteen firing positions in view

(Centre) Polaris emerges from the ocean

(Bottom) The body falls back into the Atlantic

At 1.30 a.m., on a rather chilly March morning I found myself climbing a ladder on to the flight deck of a ZSG-2W airship at Lakehurst, New Jersey, expecting only to be airborne for many hours. In fact I saw an historic event. We were bound for a destination somewhat east of the normal sea lanes along the U.S. coast. There we were to carry out a dual role, that of aerial guard ship and camera platform for the first underwater firing of the Polaris missile from a submarine.

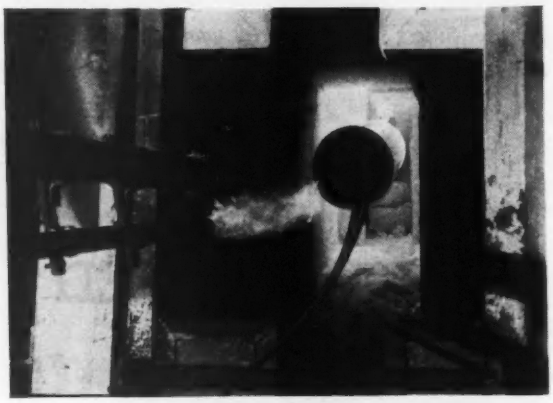
Around dawn we sighted the nuclear-powered U.S.S. 'George Washington', designed and built for the underwater firing of the Polaris, cruising on the surface at a relatively high speed. She was accompanied by two escort and salvage vessels, and, after a short interval, she submerged for the tests. 'George Washington' was in touch with the escort vessels by the underwater-sound telephone, and her signals were relayed to us by v.h.f. link.

The traditional count-down started eventually, and at zero-minus-120 seconds a patch of green marker dye appeared on the surface, not far away from where we hovered. We were at about 250 ft, and had been told that the missile would probably rise to fifty feet before power was cut off and she dropped back. At zero-minus-thirty a float surfaced and belched volumes of bright green smoke. Then the sea erupted, and the 28-ft Polaris, sitting on a sheet of flame, emerged almost obscured by a huge trail of highly coloured spray. The missile hurtled up, not to fifty feet as planned, but to more like 250 ft.

The flame went out and the Polaris toppled. The nose cone came away and dropped by parachute, while the body fell back into the Atlantic with a mighty splash. The missile was fitted with flotation gear so that the escort could pick it up later. During the rest of that day we saw five more firings, all apparently successful, but after the first experience of the rocket at eye-level we moved a little further away. . . .

It was apparent that the firing was by compressed air for the initial launch with a small charge at the first stage. At a more recent firing in the Pacific, Polaris rose to 1800 ft; but the first tests, which I witnessed, demonstrated that the missile **could** be fired from a suitably designed submarine. The depth was not disclosed, but I can say that although the water was very clear, and the submarine was perfectly visible from the air when at periscope depth, we could not see her at all during the firing stage. It is safe to say that she must therefore have been down at least 100 ft.

A modern continuous glass-works does not quite run itself, but need for great numbers of skilled craftsmen has been replaced by need for engineers to look after machines and instrumentation



Glass tube coming off sleeve (Propagas flame)

Automating the glass industry

by D. K. HILL

British Glass Industry Research Association, Sheffield

AT THE BEGINNING OF THIS CENTURY ALL KINDS OF glassware were made by discontinuous processes, some by techniques which had not changed for 2000 years. Sheet glass was made by blowing a cylinder of glass, splitting and flattening it by heat; plate glass by pouring the molten contents of a large refractory crucible between rollers onto a flat table; tubing entirely by hand; containers (jars, bottles, ampoules, etc.) by hand-gathering glass from a furnace end and then either mouth-blowing into moulds or—most up-to-date at that time — using compressed air and a semi-automatic machine. Even melting of the raw materials was still to a very large extent discontinuous (as with the present-day open-hearth or crucible steel melting); the continuous 'tank' furnace, into which raw materials are fed at one end and from which finished glass is withdrawn at the other, was only just becoming established in advanced glassworks.

The present glass industry is almost unrecognizable by comparison with the picture painted above. Sheet, plate and tubing are now produced continuously from glass as it emerges from the melting furnace, and production only ceases when the furnace has to go out for repairs—perhaps every three years. In the container industry it is now only where the quantities involved are too small to be made economically by other means that hand-forming operations survive. Instead, machines take predetermined amounts of glass from the furnace and automatically carry out the complex series of operations required to produce bottles, at speeds of up to 120 per minute. 24-hours-per-day production is only interrupted when a new 'job' is required or moulds require replacement.

A modern continuous glass-works does not quite run itself, but the need for great numbers of skilled craftsmen to carry out forming operations has been replaced by a need for engineers to look after the machines and the instrumentation of the factory. In many works, indeed, there is no need on the process side for other than such supervisory staffs, from the receipt of raw materials to the emergence of fully finished ware from the annealing tunnels. One remaining section of a glass-works, where hand operations exist to a significant extent, is in connexion with the inspection and packing of the ware. The subsequent handling into and from the warehouse is now largely carried out with appropriate mechanical aids.

How has this truly astonishing advance occurred?

In the first place credit must go to the speed with which the industry has adopted radical novelties in the field of mechanization or process operation. Within the last twelve months we have seen an entirely new concept of flat glass making not only proposed but proved and in production (the *float process* developed by Pilkington Brothers Ltd.). Mechanical devices from all parts of the world have been tested, adapted, and if successful incorporated into the processes used for one or other types of glassware. A frequently quoted example is the Corning machine, developed in the U.S.A., which is producing glass envelopes for lamp bulbs at speeds of over 1000 per minute in the U.K. (again, for 24 hours per day).

Mechanization alone, however, is not the sole clue to the progress of the industry. To make mechanization worth while a number of criteria must be satisfied, primarily that the glass fed to the machines must have a controlled temperature, controlled viscosity (which means controlled composition), controlled quality, and must be in controlled amounts. These factors cannot be regulated in isolation, and there must be a number of other process controls; for example, the furnace temperature distribution, furnace pressure, glass level, and—further back still—the amounts and condition of fuel, combustion air and atomizing media. Each of the relevant factors had first of all to be recognized as significant, secondly to be measured and recorded, and thirdly to be subjected to control. In very many factors the industry has attained full automatic control, feedback devices causing deviations from desired settings to be corrected. In others—for example some aspects of inspection—it has not yet been found feasible to use automatic methods.

The range of automatic devices employed by the industry is wide, and examples illustrating the range of techniques are given very briefly in the following section of this article. It should be stressed, however, that the instances cited are not necessarily those widely used. For instance, no mention has been made of automatic furnace-pressure controllers, which are very common in the industry and operate by linkage to the stack damper.

Control of furnace temperature

Glass is made from a mixture, in most cases of sand, limestone and soda ash. The rate at which this mixture can be caused to react and fuse to a homogeneous melt depends to a very large extent on the temperature schedule experienced and one essential feature of con-

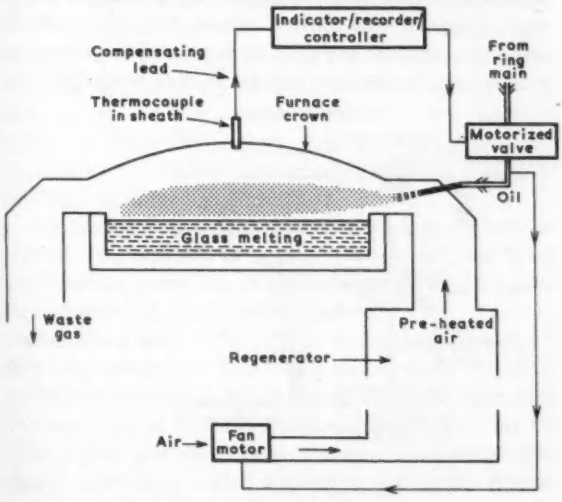


Fig. 1 Control of furnace temperature

trolled operation is the furnace temperature. Often, a number of thermocouples is used, and connected to recorders; in what is thought to be the most critical region of the furnace, a thermocouple or other device is sited for control. In the case of oil- or town's-gas-fired furnaces the control action—by the operation of motorized valves—is relatively easy. More complex problems arise with hot raw producer gas, where the temperature signal has to alter the rate of feed of coal to the gas producer. Linked with the change in rate of fuel feed is the drive to the fan supplying combustion air, so that the optimum fuel/air ratio is maintained at different fuel

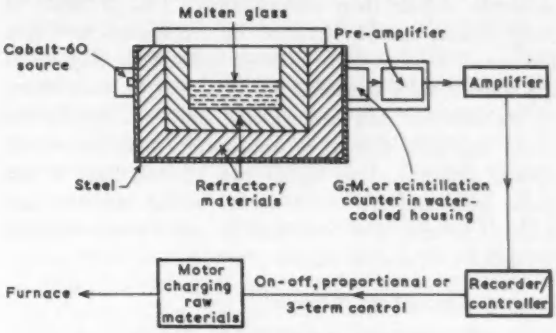


Fig. 2 Control of glass level

levels. Subsidiary circuits are used to control the pressure and temperature of the oil reaching the burners.

Control of glass level

A change in level of as little as 0·020 in. of the glass in the forehearth of a furnace of 600 tons capacity can significantly affect the weight of glass discharged to form such articles as bottles and jars, and may affect their dimensional accuracy. Of the various level-measuring devices used, probably the most common is one in which an electrode is driven downwards until it makes contact with the glass. The system (in Fig. 2) is, however, in fairly general use, and has advantages in that it can be applied to a furnace already built and does not require physical contact with the molten glass. Source-detector distances are of the order of four feet. A change in level causes a change in the intensity of gamma-rays reaching the counter, and the counter signal, after amplification, is used to control the rate at which raw materials are fed into the furnace. Control to about ± 0·003 in. has been reported.

Control of forehearth cooling wind

In bottle making, the temperature of the glass delivered to the automatic forming machines must be closely controlled (better than 2°C) to avoid excessive weight variations. The glass emerging from the furnace is usually at a different temperature from that required by the machine (perhaps 1200°C) and means of control must be provided. Immersed thermocouples are linked to valves in the combustion-air lines to gas burners, and control the glass temperature by varying the burner output. This control is limited in range and additional flexibility is achieved by providing, and altering the volume of, cooling wind. The automatic device shown in Fig. 3 works from the same sensing device as the combustion control, and may be adjusted independently: it performs the dual function of opening or closing both

the butterfly valves in the cooling wind ducts and the damper covers in the temperature-conditioning zone. A wide proportional band, with slow reset, is used.

Automatic inspection for annealing

Unless articles of glassware are cooled under controlled conditions, residual strains remain which may seriously impair their serviceability. The presence of these strains can be revealed by techniques involving the use of a polarizer to illuminate the ware (Fig. 4). If the ware is fully annealed, no light will be transmitted by the analyser, but strain in the glass will modify the beam and give rise to a measurable intensity at the optical detector. This signal can be amplified in the usual way and fed to a motor which deflects any strained article. The technique is particularly suitable for articles of simple shape.

Control of glass fibre diameter

The fibre diameter is determined largely by the temperature of the bushing through which it is drawn and

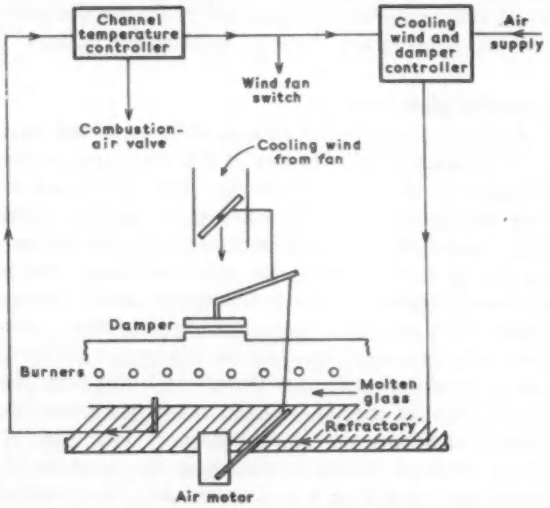


Fig. 3 Automatic control of forehearth cooling wind

by the speed of drawing. When fibres are wound on to a spool, the linear speed of drawing increases fairly uniformly from the beginning of the packaging cycle (spool empty) to the end (spool at maximum diameter). The increased speed of drawing causes a reduction in fibre diameter and to compensate for this effect it is desirable either to decrease the speed of rotation of the spool or to increase the temperature of the bushing. In one device using the latter approach (Fig. 5), a 'false temperature' d.c. signal is fed to the temperature controller which, by means of the saturable-core reactor, modifies the energy input to the bushing. The d.c. signal can be programmed by a motor-driven resistor or an electronic saw-tooth generator.

ADVANTAGES OF AUTOMATIC CONTROL

Undoubtedly the most obvious advantage associated with automatic process control in glass manufacture is the great improvement in consistency of the product. It is important to remember that the vast majority of manufactured glass does not go direct to a consumer, but first to some other industry. In that sense glass is, like coal and steel, a basic industry, and alterations in the quality and price can affect the operation and

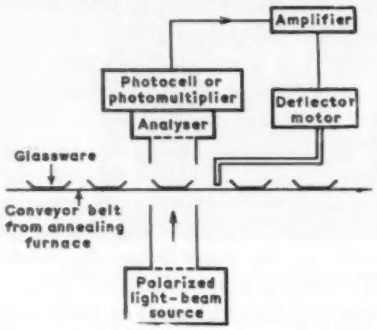


Fig. 4 Automatic inspection for annealing

economics of industries as varied as building, food preservation, electronics, lamp bulbs, cosmetics, medicines, automobiles, road lighting and so on.

The immediate effect of increased consistency has been to make glass articles suitable for a number of mass markets. In some cases, indeed, the mass market has been created because of the introduction of automatic methods of production. Such, for instance, is the case with the now common milk-bottle. Whereas forty years ago it did not exist, present production in the U.K. alone is of the order of 500,000,000 units each year. This figure is all the more impressive when one realizes that the average life of a milk bottle is of the order of sixty trips or more. Similarly, the availability of flat glass of controlled quality and dimensional uniformity has made possible the vast increase in glazing which is a significant feature of our age, not only in buildings but in other important applications such as cars, where several million square feet of toughened or laminated glass are used each year. One industry at present developing very rapidly is that concerned with

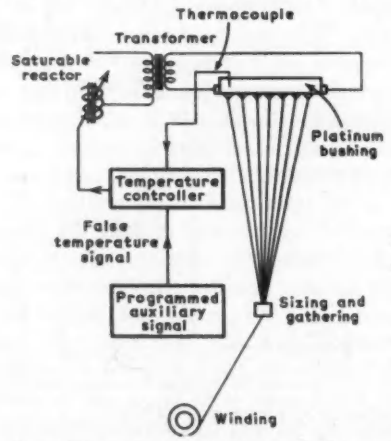


Fig. 5 Automatic control of glass-fibre diameter

glass-fibre-reinforced plastics. Already there are some spectacular achievements with this new family of engineering materials, and whilst the development of this industry is in part due to the development of 'compatible' plastics materials, the availability of substantial

quantities of highly consistent glass fibres is a major contribution.

An indirect advantage to the community as a whole, rather than to the glass industry itself, arises from the fact that glass products are now *known* to be consistent (to within astonishingly close tolerances, when one considers that they are made at high temperatures from a material which then has the properties of treacle). Thus the packer of beverages can mechanize his filling lines to cope with hundreds of bottles per minute, or the safety-glass manufacturers can set up a plant and know that the same treatment of each piece of glass will produce the desired result. In such ways the advantages of more economic operation can be passed down the line until the cumulative effect on the ultimate consumer is significant.

Thus, we have seen that improved consistency of products has had the effect of increasing the demand. As the demand has increased so has it been possible to plan the operations of the glass-works more efficiently, by making it feasible to produce long 'runs' of given articles. The net effect, as far as customers of the industry are concerned, has been that the glass industry has succeeded to an unusual extent in holding down the price of its products, most of which are themselves much better in quality than they were a bare twenty-five years ago.

A significant contribution to economic efficiency has been achieved in the control of furnace operations—combustion of fuel, melting of raw materials and homogenizing the melt. A crude yardstick of the performance of furnaces is provided by an assessment of the number of square feet of melting area required to produce one ton of glass per day. Whereas twenty years ago a typical 'good' furnace would operate at about 10 ft²/(ton/day) in the container industry, and the average might have been about 12, to-day there are a number of works showing figures of 6·5 or even lower. In other words, furnaces of the same melting area will now be producing at least 50% more glass than formerly, and because of the various process controls this glass will generally be of far higher quality.

Another way of looking at the melting problem is to consider the number of tons of glass which are being produced for every ton of coal consumed (or the calorific equivalent of coal, as oil or gas).

Over the period 1923–1927 an average figure was 1·5 tons of glass per ton of coal for the container industry; the present average value is almost certainly more than 3·0 whilst some furnaces are known to operate at 3·5 tons of glass per ton of coal or better. Comparing these figures with those which applied to the earlier discontinuous or hand-worked furnaces, we find that the glass/fuel ratio for the latter was generally less than unity. A large part of this improvement is associated with improvements in furnace design, heat recovery systems, better refractories and the like, but first instrumentation and then control have played a vital part in determining optimum operating conditions, and in ensuring that conditions appropriate to different furnace loads are set up without wasteful delay, and are maintained. When one considers that over a million tons of glass are melted in the U.K. each year for containers alone, it will be seen that, by refining the control systems, the industry has made a significant contribution to the national fuel economy.

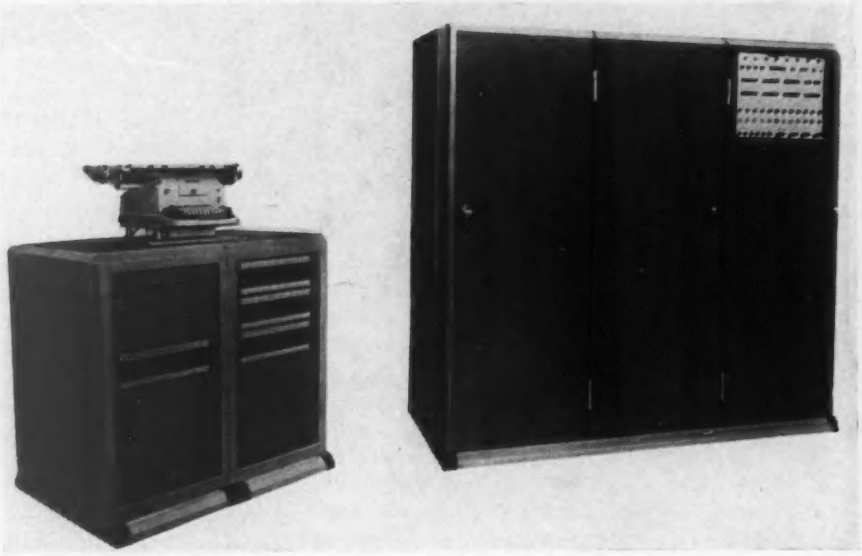
Mention has been made on a number of occasions of the rather intangible feature 'glass quality'. Many aspects of this can be recognized, for example the presence of bubbles, blisters, streaks, non-glassy inclusions, inhomogeneities, etc. may detract either from its appearance or affect its serviceability: because of multiple reflexions even the faintest tints may show up as undesirable colour: inadequate annealing could affect service behaviour in some applications. Control of some of these features goes back to the handling, weighing and mixing of the raw materials, and a notable number of glass-works have in recent years installed fully automatic plant for carrying out these operations and conveying the mixture to the furnace. Other factors relate to the melting conditions, which as we have seen are now under an advanced degree of control, whilst still others depend on conditions in the delivery system feeding molten glass to the forming machines. Here again automatic control has produced a major decrease in the proportion of defects and, by ensuring that the machine gets what it wants, has enabled machine speeds to be increased to the sort of figures quoted earlier. Annealing is now everywhere carried out in controlled-programme tunnel furnaces.

Human aspects

We have seen earlier that the traditional glassblower has virtually disappeared from modern high output factories and his place has been taken by the scientist, technologist, and engineer. However, all machines and control units require support services—machine-tool shops, instrument mechanics, maintenance etc. and the result has been not so much to displace labour but to replace one set of skills by another. Further, the vastly increased output has led to the employment of increased staffs for dealing with the finished ware, on inspection, packing and transport. The labour force of the industry has in fact increased year by year. There is, too, a valid contention that to a very large extent the unpleasant aspects of factory operation have been reduced over recent years. It is no longer necessary for men to be engaged on heavy shovelling of raw materials, or exposed for long periods to the intense radiated heat from the furnace.

Summing up, the glass industry is one for which the word 'automation' is only a new expression of an already accepted attitude of mind and physical accomplishment. Glass-works are not *fully* automated—they probably never will be—but by comparison with other basic process industries their achievements are not negligible.

PART 1



Ferranti Argus process control computer

Whys and wherefores of the techniques of digital process control, which are now rapidly gaining ground in the United States

Process control by computer

by **R. A. MORLEY** *and* **M. B. WOOD**

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THE CONTROL OF INDUSTRIAL PROCESSES BY DIGITAL computers has arisen as a natural consequence of two post-war trends. On the one hand, as a result of parallel developments in logical design and in components, digital computers are becoming sufficiently flexible and reliable for on-line use. On the other hand, military equipment and systems are so much more complex that man can no longer control them unaided.

Early complex control problems, such as occurred in setting up command guidance for the Nike anti-aircraft missile, were solved by means of special-purpose analogue computers—a trend which has carried through into process control to some extent. Digital computers were not, at that time, sufficiently fast for the Nike requirements, and the accuracy of the selected analogue system was stretched to the limit. This illustrates the choice between the two methods when applied to process control. We shall not argue the case of one versus the other, since both have their places (as will be seen); but our emphasis will be specifically on the application of digital techniques to process control.

The variety of control problems arising in defence—missile check-out and count-down, automatic data handling for radar systems, airborne navigation systems, and so on—lent some incentive towards avoiding the design of special-purpose equipment for each; and attention was accordingly turned towards digital computers, then beginning to achieve speeds more appropriate to these requirements. In the first instance small general-purpose scientific computers, such as the G.P.E. Controls LGP-30, were adapted for on-line control problems; and, in fact, computers alleged to have been designed specifically for process work still bear close similarities to their predecessors. We can expect the second generation of control computers to exhibit a more marked deviation from general-purpose machines, particularly with respect to methods of storage and logical design.

The present whole-hearted adoption of the idea of computer control in America has generated a bewilder-

ing series of new terms—adaptive control, feedforward control, and so on—which tend to obscure the main sub-divisions of which these are only special cases.

Logging and alarm

The first and simplest application of computers to industrial processes is in the field of data logging and alarm. Although it is not easy to justify such installations economically, the introduction of data handling techniques into conventional process control provides a convenient first step to more beneficial applications, and induces confidence (or otherwise) in the reliability of the particular equipment used.

The advantages of using a computer rather than a more conventional data-logger for such work are to be found in the flexibility of the former. Thus, it is very often possible to compute a group parameter, compounded of a number of more usual process variables, but possessing correspondingly greater operational significance. A very simple example is gas density, which cannot easily be instrumented directly, but which may readily be computed from straightforward measurements of temperature and pressure. This technique, properly applied, not only reduces both the number of variables which have to be logged and the need for expensive quality-measuring instruments, but also makes possible a more rapid assessment of plant performance and an understanding of the process. It is particularly valuable in the case of pilot plants, the very purpose of which is the production of operating data rather than materials.

On full-scale plants, a logging computer can also be used for the immediate calculation of operating guides, the results of which are applied manually. It is a smaller step from this stage to the vesting of control action in the computer, and therefore rather important that the system should be capable of later expansion to overall control.

On the occurrence of alarm conditions, too, a computer can be programmed to carry out diagnostic routines to establish and announce the location and nature of the fault, and, where necessary, to take the appropriate remedial action; in the extreme case, this might involve automatic shutting down of the plant. Prompt and effective action on the receipt of alarms can, in some circumstances, effect considerable financial savings in terms of repair, maintenance, or reducing down time.

Thus, with the possible exception of pilot plants, a logging and alarm system has virtue only if it can later be expanded to encompass whatever control functions may be desired. This inevitably means that the initial installation will be rather more expensive than is strictly necessary at the time; but, properly planned, it should give a handsome return on the investment.

One possible extension, in the case of a company which owns a number of plants, is to the use of a small logging computer at each location, pre-digesting and storing the process data. This is available on call from a large, central, general-purpose computer, which can carry out very complex processing using the newly-developed time-sharing technique, and pass back operating guides for either manual or computer control to each plant. In order to exploit its potentialities to the full, the central computer would also be used for general scientific and other calculations.

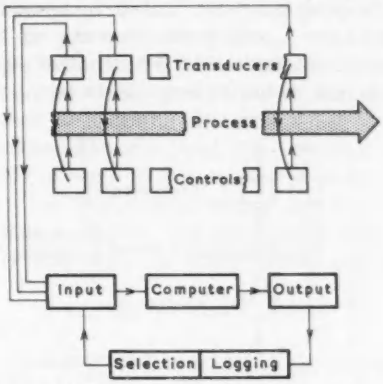


Fig. 1 Logging and alarm system

Supervisory control

Very few processes have such characteristics that they can be controlled by present methods at, or even close to, their optimum conditions. If, coincidentally, the desired condition is achieved, it cannot normally be held in the face of a random disturbance, owing to interaction of the control corrections through the dynamics of the process itself. Thus, a correction to the control loop in which the disturbance was first observed, causes its own disturbances in all the downstream loops, with varying (and sometimes very large) time delays. This generates a self-propagating family of further disturbances, which can only be controlled if the plant dynamics and appropriate lags are known.

An experienced plant engineer will have empirical knowledge of the more severe effects of this sort, and can take moderately effective action. But, even if all the effects are known, as they may be (on paper), the translation of this knowledge into the appropriate control actions is almost inevitably beyond the capacity of the human operators. The memory, computation ability and speed of reaction of a computer is needed to carry out really effective supervision of processes controlled by conventional means. The computer, then, replaces (but does not eliminate) the shift operators, and takes over their tasks of adjusting set points and logging these actions.

The installation of a supervisory control system should not be regarded as an excuse to sit back in complacency. It would be a very unusual plant indeed for which the dynamic performance could, at any time, be defined precisely, and a continuous programme of development and improvement would invariably succeed the installation.

The key to this programme lies in the care with which the logging routine has been selected, and it is

well worth the expenditure of considerable preliminary effort to devise a scheme which will give the maximum of information (as opposed to data) in the most usable form. Thus, a large company may possess its own general-purpose computer, staffed by a team of programmers, and would probably prefer to log direct on magnetic or paper tape, which, after input to the larger machine, could be analysed to provide informa-

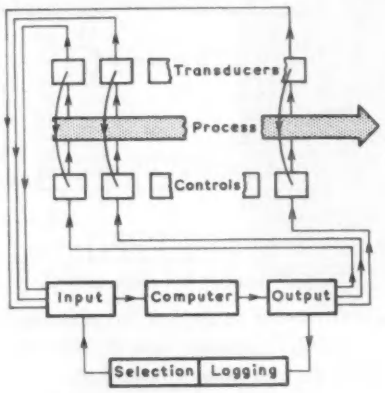


Fig. 2 Supervisory control system

tion on the process equations. A company which does not possess such a facility, and is not prepared to buy computer time, may settle for a more flexible scheme in which controlled disturbances can be introduced manually, and their results observed on a limited number of recorders, on which any instrumented or computed parameters can be selected for display. These are only two of the many possible methods.

It is important at this stage to recognize that control refinements will generally require alterations to the computer programme rather than to the actual hardware of the installation. This is not to say that it will not become desirable, perhaps, to add a new quality-control instrument or an additional logging device; but such a requirement will be the exception rather than the rule. The important consideration is that the computer itself shall be sufficiently flexible to accommodate such unforeseen changes: it should be possible to add to the storage capacity or to the numbers of inputs and outputs, after installation, without major changes in design or more than transient interruption of the control procedures.

The speed required for a supervisory control computer will depend entirely on the nature of the process to be supervised. A complex plant with very many instrumented variables, for which considerable logging is required, may need quite high computer speeds. If the process contains reactions which tend to run away, rapid response in these loops may be necessary, even to the extent of controlling certain devices directly from the computer rather than through intermediary analogue control loops. If, following the trend discussed in the previous section, it is desired to include alarm and shutting-down action, very high speeds may be needed. Each case must be treated on its merits; but, as before, it is always advisable to leave plenty of margin to cater for the inevitable development of the control system over a period of years.

Direct control

The digital control of essentially analogue mechanisms (such as pneumatic or hydraulic valves) is an established technique in the broad sense. This is seen, for example, in the computer control of machine tools, or in certain military applications of computers. The full understanding of these systems involves a knowledge of sampling servo-mechanism theory, but at this stage it is sufficient to be aware that there are many ways by which such devices may be controlled, varying, for example, from the use of valve positioners, to feeding back valve-position as a further input to the computer in order to close the loop.

By these means, in theory at least, it is possible to control a process without interposing analogue controllers between computer and plant. The advantages in the case of a new plant, or of one which is to be re-instrumented, are considerable, in that the saving on analogue controllers will back-off or overwhelm the cost of the computer installation. For about the same price as a conventional control system, the benefits in plant optimization of a supervisory control system can be obtained.

In practice, however, this procedure is not normally to be recommended until the reliability of the new generation of control computers has been thoroughly

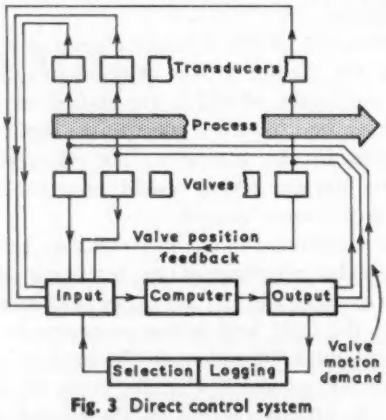


Fig. 3 Direct control system

established at a very high level indeed. Even then, it is important that the system should be designed on fail-safe lines. One possible technique (which, however, eliminates the cost saving as compared with a supervisory system), is to install two computers in parallel, with automatic facilities for switching from one to the other in defined cases of failure; another is to retain the conventional controllers, in parallel with the computer, using a similar fail-safe switching system. The benefits of such methods are to be found in the resulting quality, speed, and flexibility of control, rather than in any direct saving of cost.

An early exception to this general conclusion may be the type of plant which is large, but in which the

process is so sluggish that it can be controlled, after a fashion, by hand. The benefits in such cases are obvious; the risks are becoming rapidly smaller. No such installation has yet been announced, although the time when this will be so cannot be far off.

In addition to the need for an exceedingly high total reliability, a computer installed for direct control of plant will need to be very fast, particularly if there is a large number of control points and considerable logging requirements. As before, it will be advisable to cater for a surplus of capacity and speed.

Sequence control

The previous sections have dealt with the logging, supervisory, and direct control systems concerned, by implication, with continuous processes. The same headings, slightly re-defined, can also be applied to the wider range of processes which are normally lumped together under the title of sequence control. Some typical examples are batch production, packaging, starting up and shutting down of otherwise continuous processes (e.g. power stations), traffic control, complex switching and decision problems such as those that occur in telephone exchanges or control of the national grid, oil pipeline control, and so on.

The ordered logic required to control processes of this nature is inherent in the basic concepts of digital computers. To take only one of the above examples, the starting-up of a large modern power station involves following a complex sequence of checks and actions in a given order, so that the whole unit is gradually brought up to full power at a rate which is as high as possible without transgressing safety precepts. Inputs to a computer controlling such a process would consist of values defining the 'safety status', together with the state of all controlling devices. Outputs consist of signals altering these states to conform with the desired programme, together with whatever logging is required to provide the necessary records. The sequence of operations is now sufficiently complex to introduce occasional errors on the part of human operators; and, when such stations are worked on a two-shift basis, it is clearly desirable to install a reliable and repeatable method of control.

Logging systems as such are rarely applicable to sequence control, and the nearest approach occurs in such processes as batch production, packaging, or mail-order business, where outside orders have to be filled and despatched in variable ways. This means that it must be possible to insert such orders into the computer, which controls the making-up, attaches order notes, keeps an order file, and progresses the work in the most economical manner. The primary requirement here is that the computer should have a large erasable memory, which can preferably be added in units until the desired capacity is achieved. Again, therefore, the design must be flexible.

Both supervisory and direct control have the same interpretation when applied to sequence processes. The emphasis, however, may often be shifted towards direct control, partly because many such processes can only otherwise be controlled by hand, and partly because they normally call for much slower reactions than continuous processes.

Consider, for example, the control of road traffic in a large city. Instrumentation for counting vehicles is in daily use, and could be deployed at key points to provide inputs to a central computer which evaluates traffic densities. The computer then operates traffic-lights directly in order to smooth out the density variations. Here the prime requirements are for a large erasable storage capacity and for a computing speed sufficient to deal with the many inputs and outputs needed.

Conclusion

It is clear that if we are to avoid the development of large numbers of specialized systems for carrying out the different tasks which have been outlined, then control computers must be very flexible indeed. Specifically, they should be very fast, possess variable programme and erasable storage capacities, and cater for large numbers of inputs and outputs. They must certainly be highly reliable.

It cannot normally be expected that computer control can provide significant savings in man-power. Rather will it mean that shift duties will suffer a change of emphasis, in general requiring less experience of the particular process, but more knowledge of the new method of control. The real savings are to be found in greater consistency of control, which can be translated in many ways depending on the process: economies in fuel and raw materials, reduced quality-tolerances on the product, economical use of expensive materials such as catalysts, reduced processing times, higher throughputs, reduced maintenance; these are typical examples of the benefits which may accrue. American experience on the several plants which have been computer-controlled for sufficiently long is that the complete cost of the installation, including the design study, is paid back in from three months to three years. There is no doubt that these times will be reduced as experience in the technique of optimization grows.

When plants are designed expressly for computer control, it is likely that the savings will become really significant. For example, intermediate storage areas can be reduced or eliminated; instrumentation, particularly of quality parameters, can be reduced; and the product-blending necessary to smooth out present variations in quality can be eliminated. Processes which could not otherwise be controlled can now be thought about more seriously.

The next part of this article will illustrate many of the points which have been made above, and in it we shall consider some working installations of control computers.

Acknowledgment :

Acknowledgments are due to Ferranti Ltd. for permission to publish this article.

PART 4

Elaborate measuring equipment is often built around load cells, and the signal then found to be too inaccurate. Proper regard to mechanical engineering is the answer

Load cells in industrial weighing

by **R. B. SIMS, B.SC., PH.D., M.I.MECH.E., A.INST.P.**
Davy and United Engineering Company Limited

The general equations were given in Part 1 (February), errors due to e.r.s. gauges were analysed in Parts 1 and 2, and errors in design and application were discussed in Parts 2 and 3.

LOAD-CELL CALIBRATION

The output ratio (V_m/V_n) for any type of load cell may be calculated approximately, usually to within $\pm$ 5%, at the design stage, but each cell must be calibrated accurately against known standards before despatch, and the completed installation recalibrated on site to achieve the highest accuracies. The design of suitable calibrating equipment, and methods whereby it may be checked frequently against the Standard 50-ton machine at the N.P.L., are complex problems which could only be discussed adequately in a separate paper. These problems are important, however, since the cells will inevitably reflect the inaccuracies of the testing machine, and test procedure, and they must not be neglected.

ERRORS DUE TO MEASURING CIRCUIT

The measuring circuit includes the power supply for the e.r.s. network, the interconnecting cabling, and the load indicator or recorder. The errors in this part of the load-measuring installation are:

1. Variation in the output voltage of the power supply which causes a change in load-cell calibration and a change in the electrical zero.

2. Errors in summation of the outputs where more than one load-cell is employed in the measurement.

3. Changes in the electrical characteristics of the load-cell output signal due to changes in the characteristics in the interconnecting cable.

4. Errors in the electrical measuring circuit, including lack of sensitivity and scale resolution.

Figs. 23a and b show the two possible forms of measuring circuit. The open-loop circuit is not suitable for accurate load measurement, since variations in the power supply are reflected in the overall accuracy of the system, and unless some sacrifice is made to accuracy and sensitivity by using a parallel summation, each load cell in the measuring system must have its own stabilized power supply, thereby adding to cost. Moreover, the gain changes in any amplifier used in the measuring circuit must also be added to the total inaccuracies of the system. Open-loop measuring circuits are sometimes used when transient loads are to be measured. A closed-loop system does not usually possess a sufficiently fast response, and an open-loop system with an amplifier is used to drive a high-speed recorder.

The open-loop circuit can be used, however, to provide the simplest possible method of indication. The

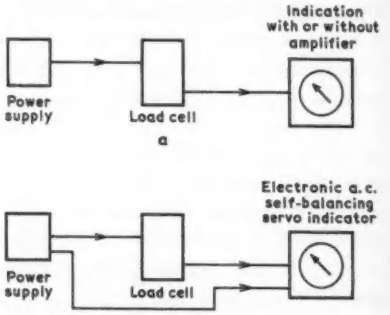


Fig. 23 Measuring circuits
a. open loop,
b. closed loop

resistance of the network may be chosen in relationship to the other variables so that the output current I_m in equation 6 may be measured with a microammeter. Usually the stress in the elastic measuring element must be 20 to 25 tons/in² at the rated maximum load; the bridge potential V_n must be 100 V and the resistance of each arm of the bridge 2500 Ω, using e.r.s. gauges formed from Nichrome wire 0·001 in. (0·025 mm) in diameter. With first-grade instruments to monitor the bridge potential and measure the output current, an accuracy within $\pm$ 1% is possible if one cell is employed, but the summation of two or more cells must be made using the parallel method (see below), and this way introduces somewhat larger errors. Nonetheless, if the working conditions are such that a 50-μA meter may be used, and the load-cell power supplies may be checked frequently, then the method has the great virtue of cheapness.

It is very difficult to devise a satisfactory d.c. closed-loop measuring circuit which is competitive economically with alternative a.c.-energized systems, and the majority of measuring circuits employ this latter technique. D.C. is only now considered, with a possible sacrifice in accuracy, in special cases; for example, where pick-up from adjacent heavy-current equipment cannot be avoided, and in some forms of conveyor weighing. Thermo-electric effects at the junction of two dissimilar metals must be avoided in d.c. systems. Practically speaking, these only occur in unsymmetrical temperature fields, and the load cells and circuits are—or should be—electrically and geometrically symmetrical about the input-output axis. The effect is discussed in detail by Stein (*15*).

The a.c. measuring circuit solves many of the difficulties in achieving highly accurate measuring systems at a reasonable cost. The power supply becomes simply an accurately made, multi-tapped transformer. Each load cell is separately supplied from the one transformer, which also energizes the slide wire of a standard a.c. self-balancing potentiometric indicator or recorder. The cells may be summed either by a resistance network which takes an *average* voltage, or, preferably, in a series system which has the great advantage of adding together accurately all the outputs, thereby increasing the signal level. The major problem of the effect of input-voltage changes on overall accuracy is then solved cheaply, and completely. The only other problem which remains is the adjustment of the phase of the individual load-cell signals to that of the slide wire. Phase matching has been the subject of a great deal of research, and now becomes a problem only in systems intended to indicate accurately at the $\pm 0{\cdot}1\%$ level and better. The only real disadvantages in the a.c. measuring circuits when compared with d.c. systems are that the bridge zero coefficient Z in equation 7 contains resistive and capacitive terms which must be separately balanced, and a great deal more care must be taken in laying the interconnecting cabling. It must be screened to avoid pick-up, and the type and quality of cable must be chosen with care to avoid changes in capacity balance with time.

A self-balancing potentiometric indicator or recorder which will accept an a.c. signal is therefore used in closed-loop measuring systems, and since this is a relatively expensive piece of equipment it must be chosen with care. As the cost of the equipment is determined by the quality of manufacture and servicing facilities, so also are reliability in service, speed of response, sensitivity, guaranteed accuracy of measurement at a given signal level, and the size of the indicator dial or recorder chart.

The speed of response of the indicator or recorder is an important consideration in process control. In the tank-weighing installation shown in Fig. 15, load changes are slow and an indicator in which the pointer takes 30 s to travel from zero to full scale (or 30-s response time) is adequate, whereas in the tank installation in

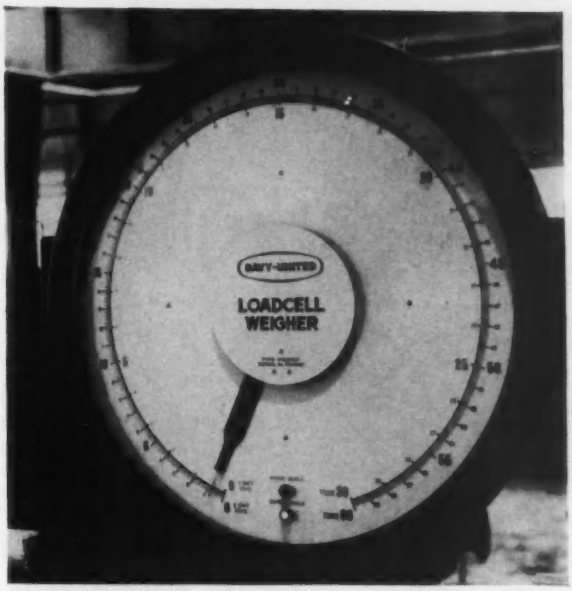
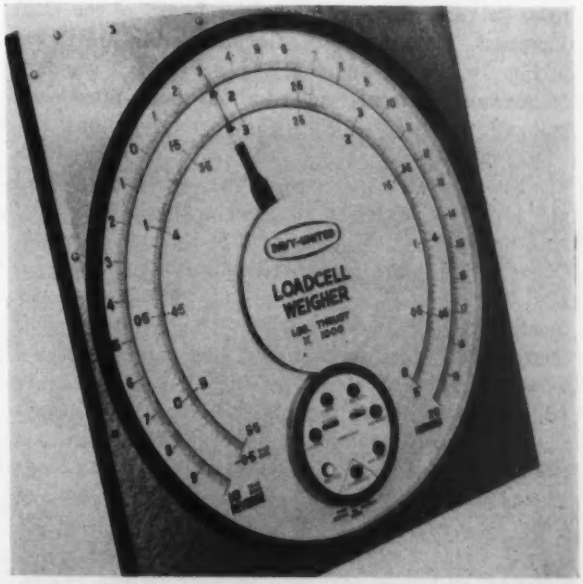


Fig. 24 Dual-range indicator for the scale-car shown in Fig. 22

Fig. 7a or 7b, a Honeywell Electronik indicator with a $5\frac{1}{2}$-s response time is fitted since it is used to measure out 5-ton increments of load from a large tank. In a rolling mill a far faster speed of response is needed, and the normal loadmeter installation employs a potentiometric indicator of special design (the Davy-United 'Highspeed' system has a response time of less than 0·5 s). The higher-speed indicators are, of course, more costly, and requirements should be carefully considered before a fast-acting system is installed.

The sensitivity and accuracy of measurement at a given signal level are also important points to consider, particularly when high accuracy and high speeds of response are called for. A good potentiometric indicator or recorder will be sensitive to a change in signal of 4 μV, but design of the equipment, usually resolution of the slide wire and backlash in the drive, limits

Fig. 25 Multirange scale expansion on an aero-engine test bed



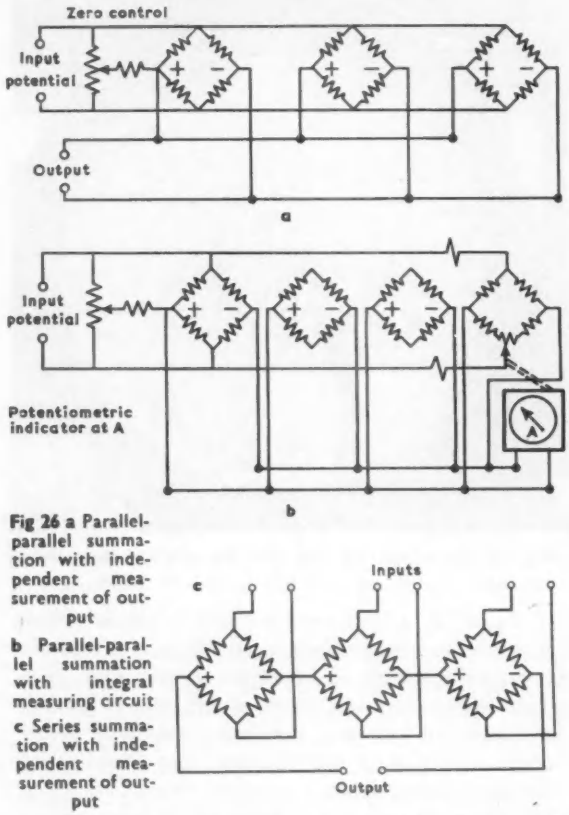


Fig 26 a Parallel-parallel summation with independent measurement of output

b Parallel-parallel summation with integral measuring circuit

c Series summation with independent measurement of output

the measuring accuracy to ± 0·25% of full-scale deflexion, whatever the signal level. It is impossible to guarantee a load-cell installation to accuracies better than ± 0·3% of full load, at any loading when the cell output is applied directly to an unmodified standard potentiometric indicator. However, experience has shown that, with a good instrument, accuracies as close as ± 0·15% may be reached on standard equipment, and this is about the limit of resolution of the indicator scale, which is usually about 30 in. long (750 mm). Clearly, if accuracies in the region of ± 0·05% to ± 0·1% are to be realized, the instrument inaccuracy must be reduced and the effective length of the scale increased. Three methods of achieving this are shown in Fig. 7b, Fig. 24 and Fig. 25. In Fig. 7b a standard Honeywell Electronik indicator has been fitted with manually operated scale expansion, the additional circuitry being fitted to the auxiliary tray beneath the indicator. In Fig. 24 an indicator with a 36-in. diameter dial and a 95-in. (2650 mm) scale-length has been fitted with two ranges, 0–30 tons and 0–60 tons, for the scale-car weighing shown in Fig. 21, so that accuracies considerably better than ± 70 kg and ± 150 kg may be reached, depending on the load in the scrap pan. The indicator has a response of 5½ s. The installation for a jet-engine test bed, shown in Fig. 25, not only has a 36-in.-diameter scale, but also six-range scale expansion so that an accuracy of ± 10 lb can be reached in 30,000 lb on a scale of − 10,000 lb to + 20,000 lb. Scale expansion is obtained by partly restoring the balance of the load cells with a set of precision resistors which are switched into the circuit. In Fig. 25 the outer scale is calibrated − 10,000 lb to + 20,000 lb, and the inner scales cover a range of 5500 lb. If a thrust of + 16,550 lb is to be measured, the resistor network balances the load-cell output by an amount equivalent to − 10,000 lb + 25,000 lb = + 15,000 lb of load, and the residual output of 1550 lb is displayed on the positive range of the inner scale, covering the load-range 0–5500 lb to an accuracy of ± 10 lb. The scale expansion is carried out automatically by a set of switches driven by the indicator, and the total load is obtained by adding to the scale reading the amount of load offset by the resistors, which is indicated by one of the set of lamps on the inner dial. The manually operated version of this system is possible at a very reasonable cost, and is adequate where changes in load take place slowly but require precise measurement.

More than one load cell is used in the majority of industrial applications, and errors may be introduced into the measurement of total load by the method employed in the summation. Figs. 26a–c show three possible circuits arranged for summation in three load-cells, although the method is applicable to any number. The parallel-parallel summation shown in Fig. 26a has been widely used, but has a number of disadvantages which cannot be ignored. Its principal advantage is that only one source of power is needed to energize the load cells, and in d.c. systems this is important since only one stabilized power supply is required. In this arrangement the slide wire of the self-balancing potentiometric indicator must be separately energized, and unless the two power supplies are kept to precise ratio, errors in calibration, or measurement, will occur. The major objection to this type of summation is that the bridges will load each other if they differ mechanically and electrically and carry different loads, introducing unacceptably large errors in the measurement of total load. This problem has been discussed by Sims, Place and Morley (*4*). Moreover, the total output of two or more equally loaded identical cells summed in parallel is the same as that of one of them, so that the method gives a lower signal level than the theoretical maximum, and in highly accurate systems the loss of sensitivity in the measuring circuit may be objectionable.

Fig. 26b shows a modification to the simple parallel-parallel summation, intended to overcome the errors introduced by the two power supplies when using a self-balancing potentiometric system of measurement with d.c.-excited bridges. A fourth bridge is added, built from precision resistors, which is energized from the common supply and is unbalanced by the servo-system by an amount equal and opposite to the sum of the load-cell outputs. This method, whilst convenient when the use of d.c.-energized cells is unavoidable, nonetheless precludes achievement of the highest accuracies because of interaction between the networks.

In the third system shown in Fig. 26c, each load cell is separately excited and avoids the objection of inter-

action. It is a practical method only for a.c. systems as described above. The outputs may be added either in parallel, by a resistance network, or in series. The former is the easier to achieve a capacity balance in the zero term, Z, in equation 7; The latter gives the larger output, and is preferable. The highly accurate systems shown in Figs. 24 and 25 use this method of summation, since it provides the highest possible output for a given load-cell-bridge excitation. Providing the load cells themselves are truly linear in output with load, this method of summation will give an equally linear summation, so gaining simplicity in the measuring circuit.

LOAD-CELL APPLICATIONS

In the above sections of the article an account has been given of the possible causes of error in load-cell weighing systems, and the methods by which these errors may be avoided. A number of load-cell applications have already been illustrated, chiefly examples concerned with tank weighing and engine-thrust measurement. A brief survey is given below of the more specialized applications of load cells. The advantage of 'packaged precision' which a load cell brings to mechanical design cannot be too greatly stressed. Provided that the cells are seated on a solid base, machining is avoided on the structure, costs are saved on fabrications, and the extensive civil engineering, so common for lever weighing machines, is greatly reduced.

Crane weighing

There are three methods of crane-weighing with load cells. (1) The cell may be built into the crane hook as shown in Fig. 27. The toroidal design is particularly suited to this application, and the toroidal element has been modified to take heavy side-thrusts. The overall height of the 15-ton cell shown in Fig. 27 is only 1·60 in. (40 mm). (2) The cell may be suspended from the crane hook, as a detachable unit. This method is of use only for an occasional check weighing, since the cable tends to trail and is easily broken if the cell is not treated carefully. (3) Rope tension may be measured and the hook load taken to be proportional to it. Some error is inevitable in this method, since bearing and rope friction are unavoidable, and whilst the latter may be reduced by using roller-bearing sheaves, rope friction is large and may vary. Measurements of rope tension, however, may be made a reliable indication of hook load by measuring as many falls of rope as possible close to the hook. In many applications it represents the only possible solution to crane weighing. In accurate measurements of the weight of molten metal, for example, load cells cannot be placed near the ladle beam (although some Continental manufacturers have suggested it), and the measurement of rope tension at the crane crab by water-cooled load-cells represents the only solution.

The fact that the measurement is made electrically, and the load indicator pointer is driven by a relatively high-torque geared electric motor, makes it possible to custom-build the weighing application to suit the plant. Fig. 28 shows a digital display built for a crane in a high-production engineering shop. The crane is used for loading goods on to transport, and the tally clerk's job is simplified since the weight appears in easily-read digits on the side of the cab. The interconnecting cabling is made by spring-loaded reels. A Board of Trade certificate has been granted under Section 6 of the Weights and Measures Act for this load-cell crane weighing equipment, either built into the crane hook, or suspended from it.

Fig. 27 Load-cell crane-weigher built into hook, for which a Board of Trade Certificate has been granted

Weighbridge

Load cells may be used in the larger road and rail weighbridges with considerable cost economy in the overall installation. Fig. 29 shows a section through a 60-ton rail weighbridge. The platform is supported either by four toroidal or four precision load-cells, depending on the application, yet the foundations are only 24 in. deep (600 mm) overall, and consist simply of a concrete-lined and drained pit with four reinforced corners, comparing favourably with the elaborate civil engineering for the conventional lever systems of large weighbridges. These load cells may be fitted with shock absorbers which will also protect them against gross

Fig. 28 Digital indication of hook load

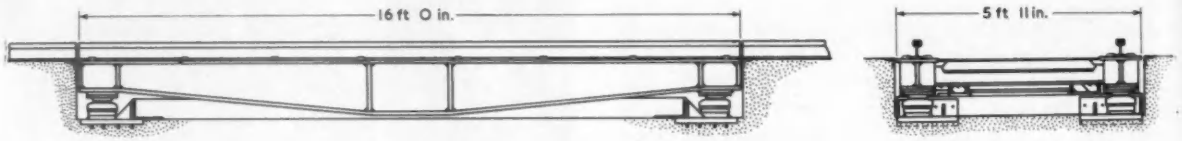


Fig. 29 Drawing of section of load-cell weighbridge

overload. The scale-car seen in Fig. 22 shows another type of weighbridge—the mobile scale-car—where load cells have a great many advantages over the conventional lever machine, particularly in reliability and low maintenance.

Tank weighing in dangerous atmospheres

A certificate of intrinsic safety has been obtained for the toroidal and precision load cells described earlier. A modification is made to the normal circuitry and the standard design of potentiometric indication may be used, provided that it operates outside the dangerous area, or is contained in a flameproof enclosure.

Roll loads and strip tension

The e.r.s.-gauge load-cell was first produced for rolling-mill research, and a range of specialized equipment for this duty is now made for production mills. Toroidal load cells have also been fitted to the rolls of calenders, which is a similar application. Their chief use is to ensure that uniform load is applied along the roll barrel, i.e. the loads on each roll bearing are equal, and that a uniform load is maintained. In rolling mills the load-meters are used in automatic gauge-control systems to compute the thickness of the rolled product (*16*), and to make a correction for any variations which occur.

Load cells have also been used for the measurement of the tension applied to material produced in strip form (*17*). The material is deflected over a measuring roller, and the downward force exerted by the strip is measured by cells placed beneath the roller.

Conveyor-belt weighing

A description of the use of load cells in conveyor-belt weighing has been given by Lowe (*18*). Load cells have been used for weighing on belts passing less than 100 ton/h to a large self-propelled dragline with conveyors moving up to 2000 ton/h. The advantages of load cells are obvious. Instead of the complex mechanical and electromechanical equipment associated with lever machines and their integrating equipment, one conveyor idler is mounted on two modified weighbeams as shown in Fig. 14, one at either end, and no drastic alterations to plant are required. The cells may be supplied with a signal proportional to conveyor-belt speed so that a correction may be made for changes owing, for example, to speed droop caused by the electrical characteristics of the drive, and the standard potentiometric recorder fitted with integration will maintain a summation of the load up to six-figure totals. The installation is appreciably cheaper than conventional lever systems. It has also the great advantage of not having moving parts; an important point, since so many conveyors transport a dusty burden which so easily damages knife edges.

Specialized load cells

The small dimensions of the load cell make it possible to build equipment for specialized applications without undue cost. One of the best examples of this is the precision load cell shown in Fig. 30. This is built into a hydraulic jack, to be used as a substandard for load calibration. Load cells have been designed for measurement of the proof stress in reinforcing bars, the safe load on hot metal shears, the load on individual wheels of locomotives, and a number of other similar applications where a simple solution is unobtainable by alternative equipment.

In the account of load cells which has been given in this article, emphasis has been put on the mechanical and electrical design required to realize the accuracies called for by modern industrial processes. Given an accurate electrical signal, the plant instrument engineers are well able to devise circuits to suit their requirements from the abundance of standard and well proven components available to-day. So frequently, however, elaborate measuring equipment and control circuits are built up using load cells to give the primary signal of load; and when put to the test the signal is of inadequate accuracy. The problem of accurate load measurement using load cells belongs essentially to the domain of mechanical engineering, and if this article has demonstrated the point, its purpose will have been achieved.

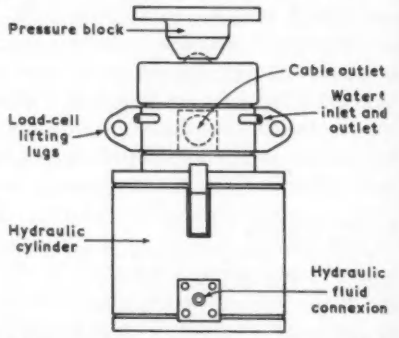


Fig. 30 Outline of precision load-cell built into hydraulic ram

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End

Switching is basic. Here is an introduction to the new solid-state devices that are increasingly taking over this job in industry

Solid-state relays and switches

by **D. H. ROBERTS**

Caswell Research Laboratories, The Plessey Co. Ltd.

ONE OF THE MOST BASIC ELECTRONIC FUNCTIONS IS THAT of switching, whether this is done by toggle, post office relay, thyratron, or transistor. In the application of semiconductors to this function there are usually two criteria under consideration: speed, and power-handling capacity per unit weight or volume. The former is all-important in the electronic computer and the latter in the control of power for heavy engineering. In general these two requirements conflict, and whereas one device might switch with a rise time of less than ten millimicroseconds, and another be capable of switching and controlling several kilowatts, the simultaneous achievement of these two virtues in one device is unlikely—and probably unnecessary.

In the following, devices of the post-transistor era will be discussed; all but one are most relevant to the fast computer. The exception is the controlled rectifier, which has great potential in the power field. Some attempt will be made to give a physical picture of the operation of these new devices, their characteristics, and some immediate fields of application.

PHOTOCONDUCTIVE SWITCHING

Highly sensitive photoconductive materials, such as cadmium sulphide and cadmium selenide, can be prepared as single crystals, ceramic blocks, or thin films, such that the ratio of dark to light resistance can be $\sim 10^6$. It is thus possible to 'switch' the impedance by means of a light signal from an orthodox light-source—or better still from an electroluminescent panel which has a shorter rise and decay time.

The virtue of this system is that a large number of switching elements (with no moving parts) can be assembled in a small space. Hundreds per square centimetre is quite a reasonable figure. Since these are now light-operated there is no complicated wiring problem, and no fear of 'cross talk'. The switching speed is limited by the response time of the photoconductor, and it is unlikely to fall below the millisecond level with presently available materials. However, even this speed is adequate for many applications.

Recently, Loebner of R.C.A. has suggested that there could be built up a new class of electro-optical computer based on this type of device. The basic element is illustrated in Fig. 1a. When the photoconductor is dark its impedance is greater than that of the electroluminescent element, so that there is insufficient electrical power applied to excite the latter. If a pulse of light falls on the photoconductor, however, its impedance falls so that it switches on the electroluminescent element. The radiation emitted can be sufficient to keep *PC1* 'on' even after the original light impulse has disappeared. Thus we have a memory system that can be switched off by a second optical pulse on *PC2*. In Fig. 1b is illustrated an OR gate. Many other orthodox circuits can be simulated by this technique. For large

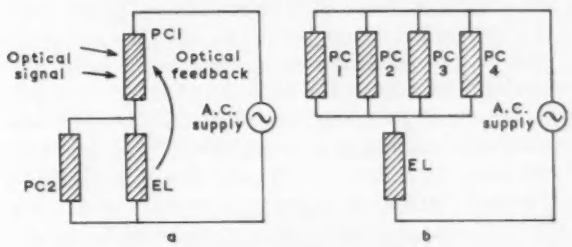


Fig. 1 Electro-optical logical elements

stores, as used in data processing, where speed is less important than size and cost, this technique could well become very important in the future.

LOW-TEMPERATURE SWITCHES AND MEMORY SYSTEMS

Superconducting devices

It was first suggested by Buck (1956) that one aspect of superconductivity might have practical use in computer circuits. For all superconductors the presence of a magnetic field in excess of a certain threshold value (H_c) restores normal conduction. His device consisted in the first instance of a superconducting tantalum wire surrounded by a few turns of niobium wire through which could be passed a current sufficiently high to generate a magnetic field $> H_c$ for tantalum, so switching the tantalum to its high-impedance state. This is analogous to a relay, except that the high impedance is far from infinite. By suitably arranging the geometry it is possible to achieve current gain greater than unity, and hence to use the output of one *cryotron* (as this device is called) to control another.

Cryotrons can be used in many logical circuits such as AND and OR gates, matrix switches, and shift registers (Buck 1956, Slade and McMahon 1957). The speed limitation of this type of device is set partly by the thermal time constant of the rise and fall in temperature produced by Joule heating during switching, and partly by eddy-current delays limiting the speed with which the transition spreads through the wire. Both these effects can be reduced by the use of thin films on suitable subtrates, and the future application of cryotrons is most certainly tied to the thin-film techniques—either evaporation or electrodeposition. Currently most laboratories are concentrating their effort on thin-film technology, endeavouring to achieve greater understanding of the influences of substrate material and temperature, degree of vacuum used, deposition rate and so forth, on the structure and the superconducting behaviour of evaporated metal films.

More recently, storage has been achieved using the persistent current in a superconducting ring. In one form it is called the Crowe cell (Crowe 1958), but whilst this could be a very useful device in a low-temperature computer it is not such a close analogue to more orthodox devices as is the cryotron, and as a complete descripton of its operation would occupy the whole of this article, nothing more will be said.

Impact ionization switch

In a semiconductor such as germanium, at low temperatures (in the region 4 to 20°K) there are comparatively few electrons free to conduct. As a result the impedance of a small bar measuring $10 \times 1 \times 1$ mm can be several megohms. If the applied voltage is increased, the kinetic energy of the free electrons increases until electrons collide energetically enough with atoms of impurity (such as arsenic) to produce more free electrons. At a particular value of the applied field the rate of production of new electrons exceeds the rate of recombination, so that an 'avalanche' occurs and the resistance of the specimen falls by many orders of magnitude. The resulting current-voltage characteristic is shown in Fig. 2 (Rediker and McWhorter 1958).

Apart from its considerable fundamental interest, this process has the following importance:

(i) Its occurrence at low temperatures makes it suitable for use with the superconducting systems we have already discussed.

(ii) Being a bulk phenomenon, it does not require any elaborate techniques for the fabrication of diffused or alloyed junctions.

(iii) Many switches can be constructed on a piece of germanium $10 \times 10 \times 0{\cdot}5$ mm (hundred switching elements without any difficulty). Fig. 3 shows a photograph of a hundred-element switch constructed by B. L. H. Wilson and B. Fitton (Caswell Research Laboratories).

(iv) The rise time of the current pulse following a voltage signal pulse is very short. Typically, for applied fields of four times the minimum switching field, switching times of ~ 15 mμs have been observed (Hayes, 1959).

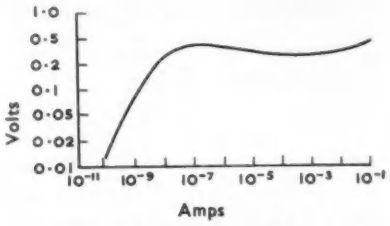


Fig. 2 Impact ionization characteristics

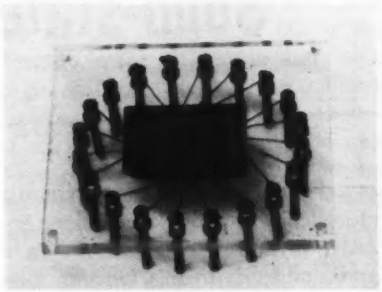


Fig. 3 Impact-ionization switch assembly

FOUR-LAYER DIODE

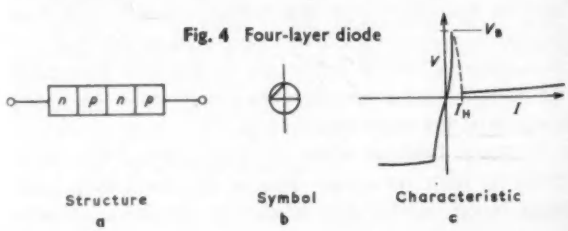
As described by Moll *et al* (1956) and by Shockley (1957), this is a two-terminal device consisting of a semiconductor wafer containing four regions (compared with the three of a transistor). Basically it can exist in two states—high- or low-impedance—the typical ratio of these values being 100 MΩ to 30 Ω. The diode can be switched from the high-impedance state to the low by increasing the applied voltage beyond a critical break-down voltage (V_B). If insufficient current is available the device will switch back to the high-impedance state (the minimum current required to hold the low-impedance state is called the holding current (I_H). In Fig. 4 are shown the structure, symbol, and typical current-voltage characteristic.

The switching mechanism depends on transistor action in the four-layer structure. At high voltages the current multiplication is sufficient to bias the middle junction forward, where originally it was in a reversed or blocking-bias condition. Applications of the device include saw-tooth wave-form generators, pulse generators and bistable switching circuits. Given a device of small size, it seems possible that switching speeds of 10 mμs may be possible with this new semiconducting switch.

CONTROLLED RECTIFIER

As the four-layer diode is the solid-state analogue of the neon tube, so the silicon-controlled rectifier (s.c.r.) with a third electrode is the analogue of the gas-filled triode or thyratron (Aldrich and Holonyak, 1958). The resulting current-voltage characteristic is shown in Fig. 5. As can be seen, the application of gate current causes break-down at lower voltages, and hence acts as a control. As well as multiplying electrons at high fields, which causes the four-layer diode to switch, the

Fig. 4 Four-layer diode



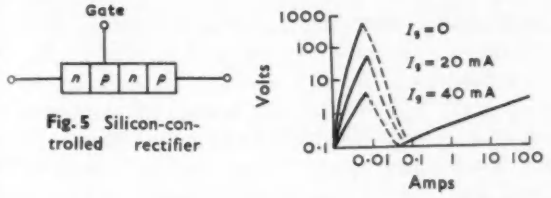


Fig. 5 Silicon-controlled rectifier

gate electrode controls because the transistor current gain in the first *npn* part of the s.c.r. depends on the current.

To turn the device off it is necessary (as with a thyratron) to reduce the current through the device to a value less than the holding current. This can be done in many ways.

What we have, therefore, is a device which can block several hundred volts in the reverse direction, and can in the forward direction be switched from low to high conductance by passing ~ 50 mA of controlling current into the gate. This will then permit high currents to flow, limited only by the external circuitry and dissipation in the device. Typically, forward currents of 20–100 A can be obtained, the built-in voltage-drop being 1–2 V.

Compared with a gas-filled triode, the s.c.r. has the following advantages:

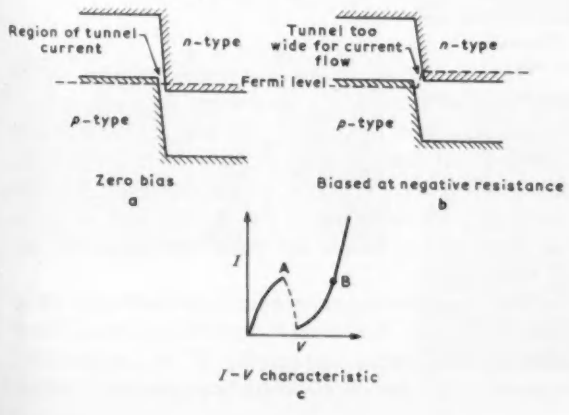
(i) It is robust
(ii) No heater supply or warming-up period is needed
(iii) Size is small
(iv) Operation is fast
(v) Forward voltage-drop is very low.

Compared with power transistors, the s.c.r. has the advantages of higher reverse break-down voltages (hundreds of volts instead of tens), and higher ratio of output to control current. It seems likely that in the next few years it will come into increasingly wide use in the industrial electronics and power engineering fields.

Probable early applications include:

(a) Static inverters—d.c. to d.c. and d.c. to a.c.
(b) A.C. static switch—welding controls, magnetization equipment, furnace-heater controls, etc.
(c) Phase-controlled a.c. switch—lamp dimming and temperature control.
(d) Regulated power supplier.
(e) Variable-speed drives.
(f) Computer circuitry—impulse switching of memory cores.

Fig. 6 Tunnel diode



TUNNEL DIODE

This device (Esaki, 1958) was invented by Dr. Esaki of Soni Corporation of Japan, and is sometimes referred to as the *Esaki diode*. It consists essentially of a *p-n* junction formed in such a way that both *p*- and *n*-regions are degenerate (i.e. tend to behave as metals), and the transition (or depletion) region is very narrow (~ 100 A.u.). In such a structure, at low applied volts, current flows by wave-mechanical tunnelling through the narrow forbidden region. As the forward bias voltage is increased, the width of the forbidden region increases, and hence the tunnel current decreases. We thus have a region of negative resistance. The energy band configuration at zero bias and in the region of negative resistance are shown in Fig. 6 together with the current-voltage characteristic.

This negative resistance can be used to make an amplifier or oscillator, probably from the audio region right up into the kilomegacycle region. Also, the switching from *A* to *B* on the characteristic is of interest in the computer field, the switching speed being in the millimicrosecond region.

As well as possessing these desirable characteristics, this device has the following virtues.

(a) Unlike most semiconductor devices it is fairly insensitive to temperature (a germanium diode operates from −100 to + 200°C).
(b) Owing to the mechanism used, this device is insensitive to surface ambient, and hence requires little in the way of encapsulation.
(c) For the same reasons this device is less sensitive to nuclear radiation than are transistors.

All in all, it seems likely to become of increasing importance in the future, not so much as a rival to the transistor as by making new applications possible in conjunction with transistors.

CONCLUSIONS

The devices discussed above have been given an undeservedly sketchy treatment; however, the references show where more details can be obtained. The purpose of this article is to introduce these new solid-state devices which will, together with devices as yet unknown, take over from thermionic valves and electromechanical relays an increasing amount of industrial switching and control. The point to be stressed, though, is that these new devices should not be seen simply as rivals to more orthodox components, but rather as devices that can perform operations hitherto impossible —and hence lead to further expansion in the industrial electronics field.

Acknowledgments :

The author is grateful to the Plessey Company Limited for permission to publish this article.

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CONTROL looks round a college that is organized to match to-day's needs in control-engineering education

Control at Cranfield

WE WERE RECENTLY SHOWN OVER THE COLLEGE OF Aeronautics at Cranfield. There are arguments for and arguments against a national school devoted to control, and these have been frequently stated in this journal. The College of Aeronautics has been suggested as a suitable home for such a school, and the following observations are offered as further factual ground for discussion.

The College of Aeronautics is a civilian educational establishment. It was established by the Government in 1946 to provide post-graduate instruction in aeronautical engineering, and operates under the aegis of the Ministry of Education. A diploma, the D.C.Ae., is awarded to students who are successful after two years of full-time post-graduate study in aeronautical engineering. The activities of the College, and thus its developing reputation, have been confined until recently to the aircraft and associated industries, which have willingly provided most of the students at a steadily increasing rate; the yearly intake is now over a hundred.

Finest teaching laboratories

With the steady build-up of staff and facilities, including supersonic wind-tunnels, an extensive propulsion-test area, and a sizeable fleet of aircraft, it was inevitable that some new activities would be developed, and in 1956 the College was chosen to provide a guided-missile course for Nato countries. This course has become a successful international institution, with an ever-widening range of nations allowed by the U.K. Government to attend, including non-Nato Switzerland, Sweden, India and Yugoslavia. It has provided the opportunity to set up what may be among the finest teaching laboratories on control and simulation anywhere in the world. These laboratories are centred in the Electrical Engineering Department of the College. With the installation of analogue computers, electromechanical, hydraulic, and pneumatic servo-systems, alongside an already established range of basic laboratories, it has been no long step to include pneumatic control equipment and data-handling devices to cover—very adequately—the principles of control engineering.

The first of the one-year full-time courses in control engineering and in flight control commenced in 1959. This, although it is an activity of the Electrical Engineering Department (headed by Professor G. A. Whitfield), is not confined there, for there are special facilities throughout the College relevant to control engineering. Typically, in the Flight Department, there is a laboratory devoted to flight telemetry, using the latest equipment for subsequent data-processing, and another specializing in flight instrumentation. The Propulsion Department provides special facilities for experimental studies of such topics as heat transfer. The Design Department is shortly to install extensive data-logging equipment for structural testing, which again will provide practical work for control students. The Department of Economics and Production is well equipped with machines for metal cutting and forming. A high-precision machine laboratory and a new 10,000-ft^2 machine-tool laboratory will house a number of numerically controlled and automatic machines. The latter department is also active in preparing an introductory short course on automatic production and control, to begin next July. This is planned to be suitable for production engineers and technical managers. Great stress is placed on practical laboratory work with real instrumentation, with even more stress on basic physical measurements, and instruction on these principles is given in the most suitable department.

Diversity

The courses on control engineering subjects in the Electrical Engineering Department are two out of several one-year 'diversified' courses, all of which lead to a new 'Diploma in Advanced Engineering' (D.A.E.). The D.C.Ae. is a respected post-graduate qualification in the aircraft industry, and the College tells us that it is determined to make the new Diploma attain the same standard.

Control engineering cannot be taught with only string and sealing wax—first-class equipment is essential. Some idea of the diversity and quality of the experimental apparatus and associated instrumentation at Cranfield

can be gained from the accompanying illustrations. In the Electrical Engineering Department there is a group of basic laboratories. The two machines-laboratories cover the design and regulation of electromagnetic machines, magnetic amplifiers, and transducers. Thermionic and solid-state devices and circuits and microwave techniques are taught in the Basic Electronics and two Radio and Radar Laboratories. A Physics and Measurements Laboratory is being equipped to ensure that students thoroughly appreciate the methods of measuring electrical and other quantities.

The Servo-mechanisms Laboratory has eight electromechanical servo-mechanism teaching rigs, each of which provides a range of set feedback-control experiments on such subjects as shaping techniques and the use of describing-function and phase-plane methods. Other electromechanical experiments available include applications of synchros and a.c. servo-mechanisms and contactor and sampling servo-mechanisms. Missile-type actuators provide the coverage for high-performance hydraulic and pneumatic systems, which include several basic control-valve measurements.

Computers

Closely associated with the Servo-mechanisms Laboratory is the Simulator Laboratory, where two standard, commercial, analogue computers are installed, along with a considerable amount of Cranfield-built equipment. This initial teaching is done on special five-amplifier trays, where summation integration and simple non-linear techniques are introduced, culminating in a few simple simulations, particularly that of the teaching servo-rig used in the other laboratory. The more elaborate studies are carried out in either of the standard computers. This laboratory also provides a service to the rest of the College (and, on a small scale, to outside industry), for analogue studies arising from day-to-day research activities.

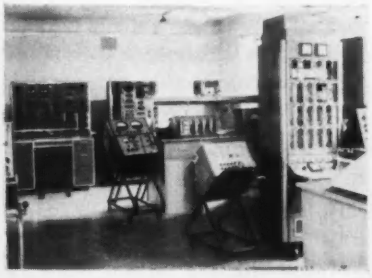
Digital aspects are covered by a new Data-handling Laboratory, which provides fundamental experiments with thermionic, solid-state, and magnetic logic and storage devices, and analogue/digital conversion techniques. Special transducers such as shaft encoders are introduced, and work leads up to complete systems such as machine-tool controls, data logging, and so on. This work will also be backed, in the coming year, by the installation in the Mathematics Department of a Ferranti Pegasus digital computer, and by card- and punched-tape-operated business machines made available by the associated Cranfield Work Study School.

Process control

The Process Control Laboratory is another recent addition, and not yet in its final situation. Here basic experiments are performed, mainly on pneumatic instrumentation. There is a comprehensive range of transmitters, two- and three-term controllers, and associated instrumentation, and the systems experiments are designed around such simple processes as water-level control and flow-control. Throughout these laboratories the ancillary instrumentation is of a high standard.

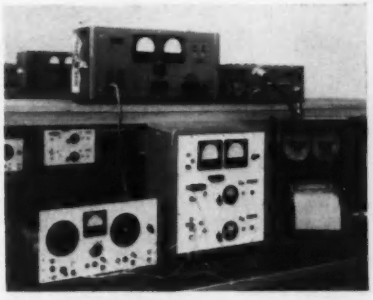
Acknowledgment

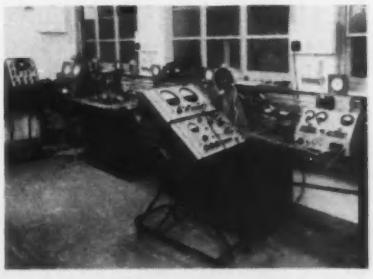
The photographs reproduced in this article have been kindly provided by the College of Aeronautics.



Servo-mechanism Laboratory

Electromechanical servo-mechanism teaching rig

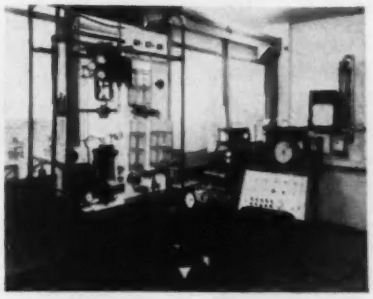


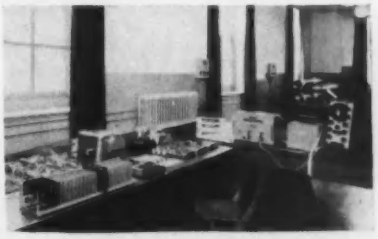


Laboratory for work on hydraulic and pneumatic servo-mechanisms

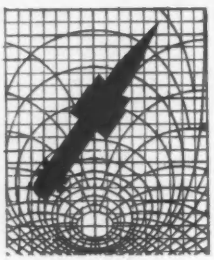
Simulation laboratory

Process control laboratory





Data handling laboratory



PART D

Basically, the design approach is to apply some well-tried assumptions, synthesize a response, and then reach more exact results by successive approximation

Hydraulic servos

by **P. D. BOYER, B.SC.**
English Electric Aviation Ltd.

So far we have: considered the missile applications of electrohydraulic systems and their properties; treated in a general way the relays, motors and pilot-stage transducers currently in use; and discussed the servo-valve, non-linearity, and pressure compensation. At the end of Part C (last month) we began an examination of hydraulic actuators, and this we continue below.

For inflow, Q_m is taken positive. Piston velocity is taken positive in the direction of expansion. Applying this to either side of the symmetrical actuator controlled by a four-way valve (Fig. 9) the relevant cylinder pressures are P_A and P_B. From Fig. 9:

$$\left.\begin{aligned} P_A &= P_1 \text{ or } P_s - P_2 \\ P_B &= P_s - P_3 \text{ or } P_4 \end{aligned}\right\} \quad (55)$$

$$\left.\begin{aligned} P_1 &= P_3 \\ P_2 &= P_4 \end{aligned}\right\}^{*} \quad (56)$$

$$\left.\begin{aligned} P_1 + P_m + P_3 &= P_s \\ P_2 + P_m + P_4 &= P_s \end{aligned}\right\} \quad (57)$$

Thus it follows that the value of $|\,dP/dt\,|$ to be used in eq. 54 is $|\,P'_m/2\,|$. So we arrive at eq. 44.

With the help of the equation of motion for the actuator, eq. 45, eq. 44 gives

$$Q_m = D_m\theta'_0 + \frac{V}{2K}\left(\frac{M}{D_m}\theta'''_0 + \frac{B}{D_m}\theta''_0 + \frac{C_1}{D_m}\theta'_0\right) \quad (58)$$

and so

$$\frac{\theta_0}{Q_m} = \frac{2\bar{K}D^2_m/VM}{D_m p[p^2 + (B/M)p + (C_1/M) + (2\bar{K}D_m{}^2/VM)]}$$

which is the transfer function of this particular type of actuator. If C_1 is zero this can be written

$$\frac{\theta_0}{Q_m} = \frac{\Omega_n{}^2}{D_m p[p^2 + 2\zeta_1\Omega_n p + \Omega_n{}^2]} \quad (59)$$

**This can be simply proved, albeit at some length, whether compressibility is significant or not. In the latter case it is plainly evident from consideration of symmetry.*

It is a fairly safe assumption that for any new and unknown actuator, sized according to the rules given later, its damping ratio, ζ_1, will not differ much from the value 0·2, unless special provisions are made. One method sometimes used to increase the damping is the provision of a small bleed passage by-passing the jack. However, this is not too reliable, as, to be effective, it must be very small and is therefore easily clogged. Moreover its characteristics vary with temperature and its presence results in a lower null pressure sensitivity (as consideration of ref. *14* will show). A longer passage, of larger diameter, would increase the compressible volume.

The bulk modulus $\bar{K}$ is very much influenced by the air content of the oil. This topic is dealt with in ref. *15*.

The choice must also be made between a three-way valve with a differential actuator or a four-way valve with an equal-area actuator. In very large bomber fin control systems, to take one example, the larger diameter of the differential type may well be prohibitive. But in the quite small actuators used for missiles a differential actuator can always be designed to occupy much the same volume as the symmetrical one.

In fact, where a rectilinear motion is called for, the single output strut of the differential actuator is often adequate, and the matching strut at the other end of the equivalent equal-area ram an embarrassment. The single strut will also be necessarily large in diameter, which is likely to be more compatible with the structural stiffness requirements. Furthermore the cost may be smaller, since only two diameters must be concentric. Against this, one half of the differential jack is always at supply pressure, and to this extent the seals on this side apparently have a more difficult job to do.

There is a strong case for much greater utilization of the differential system. No matter what its general pattern, the servo-valve can be far faster, simpler and cheaper, or alternatively faster and more precisely toleranced. These are very important considerations, since the servo-valve not only provides the second greatest delay in most systems, but of all the components (except when a gyroscope is used as the pick-off) is much the most expensive and difficult to produce, with tolerancing critically affecting linearity.

The advantage is great enough to outweigh certain other disadvantages. For comparable jacks the minimum natural frequency of the differential type is 30% lower. This occurs when hard over to one particular side. In the central position the frequencies would be

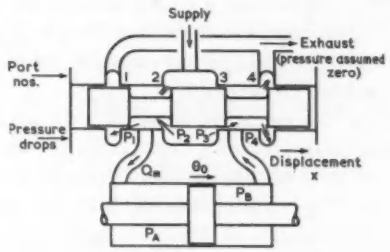


Fig. 9 Four-way hydraulic control valve and jack

equal, and to the other side the differential type is stiffer. Theoretically the push-pull (strictly push-push) hydraulic system gives a smaller second-harmonic content, though this will be difficult to detect in practice. Also the three-way servo-valve must be designed for a greater peak flow ($\times 2$). In spite of this, the overall dissipation through one complete cycle is unchanged, and ease of design is not affected. A minor point is that damping by means of a bleed short-circuiting the jack uses far too much oil to be practicable in the three-way case.

It is probably true that no fully rotational differential motor design exists. However, the requirement for full rotation is not often met in missile servos.

A given velocity demand and actuator size determines the size of the servo-valve. This broadly fixes the servo-valve frequency response, which can be, and usually is, much wider than that of the actuator. If the jack size is increased, with the aim of raising the jack's natural frequency ($\propto (D_m)^{\frac{1}{2}}$) then the oil consumption will also rise (as D_m). A bigger valve will then be needed and the new natural frequency of the valve will inevitably be lower. The valve and jack peaking frequencies must be kept apart (as is perhaps more readily appreciated than in any other way by consideration of their combined Nicholls plot), and so a compromise is usually necessary. It is obvious from the start that the compromise is heavily weighted against the actuator, which is the larger component. Its weight must be kept down and so must its oil consumption, as there is never really enough oil available. Because the designer's choice of jack area is so restricted in an application where the response requirements are high, the missile servo is especially affected by compressibility.

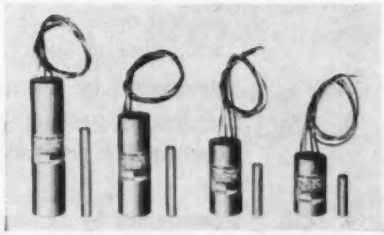


Fig. 10 Linear variable differential transformer. Available with total weight of 3·4 g, displacement ± 0·005 in. Maximum displacement ± 1 in.

Hydraulic servo pick-offs

For position measurement, potentiometers are no longer very popular. Large rotary units suffer from low-frequency wiper bounce which effectively cuts them right off, and smaller ones often have too poor a discrimination. Friction, wire wear and poor contact are also occasionally significant. However, one unusual form, a single Nichrome wire carrying a high current, and tensed to avoid thermal slackening, is very useful for precise, noise-free, and lag-free monitoring down to very low amplitudes. It forms a useful laboratory check on the fidelity of other types of pick-off.

Generally a.c. inductive pick-offs are preferable for displacement measurement. The Roehr pick-off, originally developed at R.A.E., the widely-used E-I type and

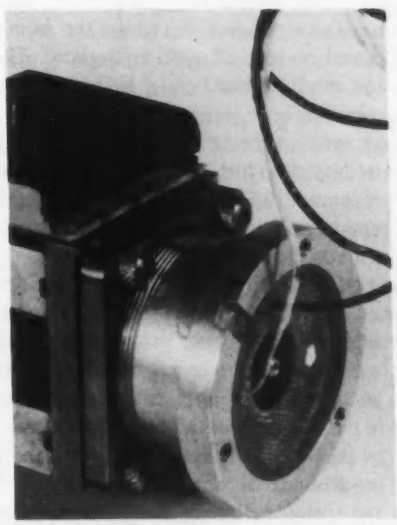


Fig. 11 Elliott–English Electric velocity pick-off, sensitivity 35 mV/(rad/s)

linear differential transformers, of which Fig. 10 represents an outstanding example, are the common alternatives to the standard synchro.

Typical tachometers, and a gyroscopic rate pick-off, are shown in Figs. 11, 12 and 13. These components form a special topic on their own, but one not so badly neglected as that of, for instance, torque motors. They are covered more completely than could be managed here in refs. *16*, *17* and *18*.

Current hydraulic servos are nearly all d.c. systems. Suitable frequency-response shaping networks can only be designed for d.c. Moreover, a.c. servo-valves are relatively new and untried and have special wear and fatigue problems (Refs. *19*, *20* and *21* indicate the trend in this field, and show that such valves are not without promise). Consequently the a.c. pick-off outputs usually require demodulation before use as feedback signals. The problem special to g.w. work here is largely confined to high-resolution servos. A first order servo, for instance, with hypothetically no loop delay and a velocity constant of 300, has a time constant of 3·3 ms. Actual servos approximating to this case may have a potential resolution of under one minute of arc. In order to take advantage of this, good smoothing is required. Effective smoothing of carrier ripple, without introducing significant phase lags in the flat response band of the servo (0–50 c/s), can only be performed if carrier frequencies are high, sometimes of several kilocycles. No simple *RC* filters exist which give sharp or narrow-band cut-off except at the expense of fairly broad-band phase modification. Inductive filters are technically more suitable but have physical drawbacks, e.g. the lighter they are, the more sensitive to saturation at minute d.c. levels do they become.

Some special problems

During the early phases of flight, while the boost rockets are firing, most ground-launched missiles roll at several radians per second, whilst the homing head remains locked on to the target throughout. The reason for this was given by Sendles in No. 4 of this series.* The interceptor missile is not usually launched straight at the target, and so the head must have an initial look-out angle at launch. Thus, as the missile rolls, the head must traverse rapidly from side to side of the frame in order to remain pointing in a given direction. This calls for high actuator flow rates.

For the rest of the flight the demand velocities will be much lower, but the tolerable aiming error and tolerable correction delay become progressively smaller. So we find that in a system where small fast valves would meet the interception requirements, much larger components are needed to meet the boost conditions. Several solutions to this problem are possible, but the solution favoured on grounds of simplicity has usually been to meet the reqirements directly in the servo-valve. Now speed of response and linearity at small amplitudes, desirable for high performance in the interception cases, are particularly difficult to reconcile with high flow rate. This creates a fairly difficult design problem. The variety of new valves still appearing in the U.S. is witness to this unsatisfied demand, although many of these types are now approaching an admirable degree of refinement. Some idea of this variety is given in refs. *23* and *25*.

Ideally it would be preferable to pivot the homing head in such a way that its inertia would maintain it with a look-out angle relatively fixed in space. By using a fully underlapped valve, giving pressure control to some extent, or alternatively by using pressure feedback, it would be possible to do this, and so to isolate the head from the frame of the missile. A demand signal would produce a pressure change to accelerate the head to the required position. This is not easy to achieve in practical heads, however, and, what is worse, underlapped valves use a lot of oil. So in most cases the jacks are flow-controlled by zero-lapped valves. These give a fairly rigid coupling between head and missile frame, and so create something of a problem for the systems engineer. (See Sendles, *loc. cit.*)

Oil dissipation is another vexed question. Many valve design problems could easily be overcome if an initial allowance of 10% say, or even 5%, of the peak flow were always permissible as leakage. Naturally, high boost rates tend to make this a more substantial demand. However, such quantities have not usually been provided for, and in partial consequence the valves become critically difficult to produce.

One unique feature is the effect of boost acceleration on the long oil-supply-lines from front to rear of the missile. For instance, the pressure drop in a pipe ten feet long at 20 *g* is over 70 lb/in². For this and other reasons it is essential to regulate supply pressure as close to the servo-valves as possible.

Design methods

There are many ways of approaching the design of this type of servo. A rough outline of a typical approach is all that can be given here.

Basically it consists of the application of one or two well-tried assumptions to synthesize a response in the manner suggested below, followed (as a successive approximation) by a more exact analysis using the values so obtained. This would be based on the techniques outlined above and in the various references. The design and manufacture of a prototype system can then begin.

It is suggested that this preliminary analysis should always be as simple as possible, for, while the cost of analysis can rarely match that of a mechanical experiment, the more sophisticated forms are entirely wasted without early support from experimental evidence.

The designer's specification

Together with circumstantial limitations of space and weight the hydraulic servo designer will be presented with a specification, such as the following for a homing head:

1. $\theta_{o_{max}}$ determined by look-out angle and consequent upon choice of navigation system, angle of launch, etc.
2. $\theta'_{o_{max}}$ determined by roll rates
3. $\theta''_{o_{max}}$ determined by roll rates and gimbal configuration or interception conditions, etc.
4. ε_{max} determined by *e.g.* radar beam width

* CONTROL, June 1959, p. 71.

5.	$\dot{\theta}_{o_{max}}(\omega)$	determined by overall missile response + target manoeuvrability, in the guidance phase
6.	M	determined by missile size, look-out angle, etc.
7.	$T(\theta,t)$	determined by body accelerations
8.	F_n	some missile structural natural frequency
9.	$K_{V\,min}$	servo stiffness or velocity constant or acceleration constant, e.g. determined by dish-missile coupling requirements or similar considerations
10.	$\int_{launch}^{impact} Q_m dt$	first approximation from missile designer based on power requirements, supply pressure, volume and weight available and previous experience
11.	P_s, P_e	supply and exhaust pressures
12.		missile acceleration as a function of time
13.		launching temperature range
14.		in-flight temperatures
15.		flight time
16.		test time
17.		shelf life

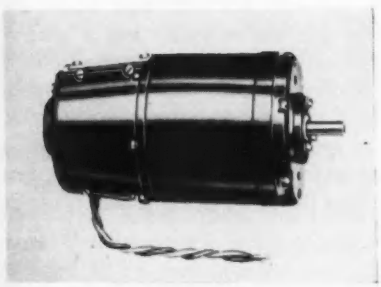


Fig. 12 D.C. precision tacho-generator, sensitivity 5, 16 or 20 V/(1000 rev/min), linearity 0·25% of ideal or 0·01% of maximum output, range 0–3000 rev/min. Low ripple level. Weight 15 oz

Naturally it is never quite as simple as this since most of these parameters cannot be finalized until the whole design is complete. Things like supply pressure must be a compromise between what the servo designer would like and what is practicable with the available means and circumstances of launch. Another important consideration is the spectrum of signal and noise levels, but this may not be known until the hydraulic system is already in use.

Preliminary analysis

On the simplest assumption of all-sinusoidal inputs, a number of relations can be used to deduce the necessary component performance.

Consider the output and input signals in the flat-response (i.e. low-frequency) region (Fig. 14).
As long as $\theta_o \simeq \theta_i$ and τ is small.

$$\frac{\phi}{360} = \frac{\tau}{T} = f\tau \tag{60}$$

and

$$\frac{\varepsilon}{\tau} = \dot{\theta}'_o \tag{61}$$

$$\therefore \quad \dot{\varepsilon} = \dot{\theta}'_o \frac{\phi}{360f} \tag{62}$$

$$= 2\pi f \dot{\theta}_o (\phi/360f) \tag{63}$$

Also

$$K_V = \frac{\theta'_{ss}}{\varepsilon_{ss}} \simeq \frac{\theta'_o}{\varepsilon} = \frac{360f}{\phi} = \frac{1}{\tau} \tag{64}$$

and

$$\frac{\phi}{f} = 360\tau \text{ or } \frac{360}{K_V} \tag{65}$$

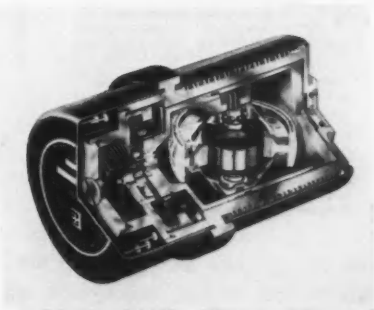


Fig. 13 M.I.G. floated rate integrating gyro G.G.49

Applying equations 62 and 63 to items 2, 4 and 5 of the specification will determine ϕ/f. Hence eq. 65 fixes K_V. This value may not be enough to meet the coupling requirement 9. It may be necessary to cut off the response with a filter to avoid the missile structural F_n, requirement 8, or some other local resonance. This filter is bound to introduce some low-frequency lag and may have to be further compensated by raising the basic ϕ/f of the servo. Thus the low-frequency phase shift per cycle per second is specified and once the overall transfer function for the design is arrived at this will determine the loop gain.

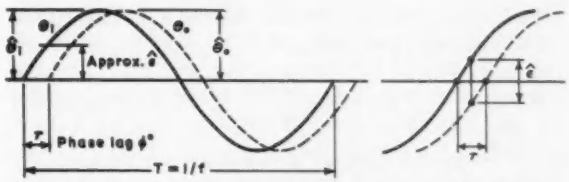


Fig. 14 Input and output jack-position signals in the flat-response band

Evidently, no step input in θ_i which exceeds ε_{max} will be permissible.

The jack design is governed by conditions 1, 2, 3, 6, 7, 10 and 11 of the specification. We have

$$\frac{P_{m_{max}}}{P_s} = \tfrac{1}{3}, \text{ say} \tag{66}$$

The fraction is determined as described earlier by the relative importance attached to linearity and efficiency, and by experience. In homing-head servos the load is primarily inertial and the emphasis is on not losing the target at any price: $P_{m_{max}}/P_s$ would be kept

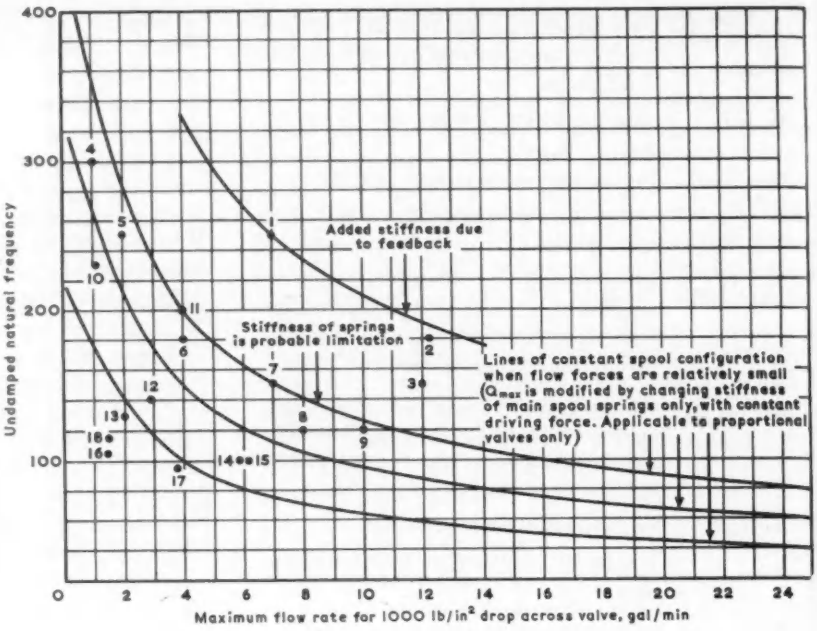

Undamped natural frequency
Maximum flow rate for 1000 lb/in² drop across valve, gal/min
Added stiffness due to feedback
Stiffness of springs is probable limitation
Lines of constant spool configuration when flow forces are relatively small (Qmax is modified by changing stiffness of main spool springs only, with constant driving force. Applicable to proportional valves only)

Fig. 15 Approximate undamped natural frequency versus maximum flow rate for various missile servo-valves (proportional and not heavily underlapped)

1 Bendix A27A with mechanical feedback (ref. 25). 2 Hydraulic Research No. 26 with mechanical feedback (ref. 25). 3 Bendix A45A with mechanical feedback (ref. 25). 4 Lear-Romec 5214 single-stage spool valve (ref. 25). 5 Bendix A8A with mechanical feedback (ref. 25). 6 Moog Series 21 and 31, latter with mechanical feedback (Dowty catalogue DE/18/1/CM/259/BW, Moog catalogue 310). 7 Bendix HRB. 8 Moog Series 32 with mechanical feedback (catalogue 310). 9 Moog Series 22 (Catalogue Dowty DE/19/1BM/259/BW). 10 Elliott B603B single-stage three-way (catalogue W4A). 11 Bendix HRA. 12 Hydraulic Research Mod. 20. 13 Vickers Spacemaster (catalogue SE98). 14 Hydraulic Research Mod. 21. 15 Sperry (Brentford) two-stage spool/spool; now industrial only (catalogue 773B). 16 Hobson 276 and 17 Hobson 319 single-stage (ref. 'Control,' Aug. 1959, p. 91). 18 Askania-Kearfott—90° phase shift only (ref. 'Control Engineering', Aug. 1958, p. 93. In all but Nos. 1, 3—6 incl. and 8—10 incl., the flow is reduced to the value for 1000 lb/in² by applying the square-root law only. Natural frequency is assumed to vary very little with pressure. In pressure-compensated valves it actually varies as $(1+P_v/P_c)^{1/2}$.

low. In wing and fin servos aerodynamic torque is a predominant feature and the luxury of a small $P_{m_{max}}/P_s$ is out of the question. Additionally a too rapid response could damage the missile. Since P_s is predetermined largely by practical considerations, $P_{m_{max}}$ is now fixed.

The load equation is

$$M\theta''_{o_{max}} = P_{m_{max}} D_m \text{ in the simplest case} \qquad (67)$$

or

$$T(\theta,t)_{max} = P_{m_{max}} D_m \text{ more generally}$$

From this D_m is roughly fixed.

If it is now assumed that the parasitic volume v between servo-valve and jack is minimized, then

$$V \simeq \theta_{o_{max}} D_m, \; v \simeq 0 \qquad (68)$$

Referring to eq. 59, C_1 in this case is zero. Thus eq. 51 may be used, giving

$$\Omega_n = \left(\frac{2\bar{K} D_m}{M\theta_{o_{max}}} \right)^{\frac{1}{2}} \qquad (69)$$

for an equal-area jack. If the jack is a comparable 2: 1 differential-area type, then V and D_m are both doubled and the same value Ω_n is obtained from

$$\Omega_n = \left(\frac{\bar{K} D_m}{M\theta_{o_{max}}} \right)^{\frac{1}{2}} \qquad (70)$$

If C_1 were not zero, it would be introduced into eq. 51 readily enough.

Taking the jack damping ratio ζ_1 as 0·2, we now have the principal delay in the servo loop, that of the actuator, completely specified.

Turning now to the steady-state flow equation, take

$$Q_{m_{max}} = D_m \theta'_{o_{max}} + 10\%$$

The latter allowance will ensure that a good response is easily achieved by the servo-valve with little friction and at no great expense.

From this and Fig. 15 it will be possible to estimate a likely frequency response for the servo-valve. Single-stage valves operated by any motor akin to the Laws relay are usually lightly damped, with a damping ratio of say 0·3 to 0·5. An amplifier with high output-impedance will ensure that the response has a second-order t.f. Two-stage valves with flapper pre-amplifiers are usually more heavily damped, with damping ratios in the range 0·5 to 1 and second-order characteristics. Servo-valves are so specialized a product, and such a wide range of proprietary valves is now available, that it can be assumed that the servo designer will take this t.f. 'off the shelf.'

For requirement 10

$$\int_{launch}^{impact} Q_m dt \simeq \frac{Q_{m_{max}}}{10} + D_m \int_{launch}^{impact} |\theta'_o| dt$$

applies to an equal-area actuator and the 2: 1 differential type requires the factor $\frac{1}{2}$ in front of the second term on the r.h.s.

It will also be necessary to check for the simultaneous occurrence of high values of θ'_o and P_m (or θ_o if $C_1 \neq 0$) as a result of the missile programme. The check for saturation conditions then ensues on Fig. 5. When assessing P_m in this context, the assumption that P_s is constant and P_e zero is far from valid. Pipe losses due to viscosity at low launching temperatures and due to boost acceleration cut down P_s and raise P_e by very substantial amounts.

This completes the design sequence. The more far-reaching check-analysis which must precede manufacture will be on the same general lines. In passing straight to the practical testing, which can only be dealt with shortly, a very long gap will now be bridged.

To be continued

A visiting Soviet lecturer argues the case for mixing feedforward with feedback in more refined control systems

Back and forward

by **G. M. E. WILLIAMS, B.SC., A.M.I.E.E.**
Northampton College of Advanced Technology

THE ROYAL SOCIETY AND THE ACADEMY OF SCIENCES OF the U.S.S.R. have been arranging the exchange for short periods of specialists in a number of fields. The purpose of these exchanges has been to enable the specialists to lecture in the host countries—Great Britain and the Soviet Union—and in return the visitors have made contacts and gained some idea of the state of their art in the country foreign to them. These exchanges are mutually beneficial in overcoming the delays caused by time, space, and differing language, and it is to be hoped that the scale of these contacts will increase in the future.

Ivahnenko

Professor A. G. Ivahnenko, of the Institute of Electrotechnics, Kiev, visited the United Kingdom under Royal Society auspices in the second half of March, and returned to his own country on 3 April. The Institute is in the Department of Technical Sciences of the Academy of Sciences of the Ukraine, and Ivahnenko directs a laboratory devoted to research on automatic control. This laboratory carries out basic studies for the Institute of Automation, which is also in Kiev. The Department was visited briefly by an I.E.E.-British Council team in May 1959.* There is some reference to the work on automatic control on page 56 of the team's report.**

Professor Ivahnenko holds other posts, teaching in the Department of Electrical Engineering in the Kiev Polytechnic Institute, and he is Deputy Editor of *Avtomatika*, a learned journal devoted to instrumentation and automatic control and published (in Ukrainian) by the Ukrainian Academy of Sciences. He is 47 years old, married to a geologist, and has a daughter aged eleven. To her we may owe the delivery in English of the three lectures given by her father in this country, for her proficiency in it has encouraged him to improve his own, and this he has shown to be not inconsiderable.

It was a pleasure to be host to this good-natured man.

Confusion nevertheless

His facility in the English language did not remove all uncertainties in the inter-communication of ideas. Some English terms were found to be used in Russian (and Ukrainian) with different or restricted meanings. Enquiry among some of those who heard him lecture, or who spoke to him directly, has produced conflicting views. These range from statements that the work described in the lectures is not new to British investigators—or, at any rate, not supported by examples of applications—to a belief that, although the underlying idea was considered in this country before 1939 and discarded, Ivahnenko has evolved a more general approach than has appeared before, and that this alone is a major contribution. Certainly, at one of his lectures, most of the audience were mistaken in thinking that the general control systems he described were confined in application to phenomena with some self-regulation. The visitor is also reported to have shown in conversation a strong antipathy for transistors and a preference for thermionic valves, but one would like to pursue this point and see whether the emotion was felt with regard only to a particular application. If the latter was the case it might be justified; but, as with many other similar matters that crystallized too late for them to be raised with Ivahnenko in person, the lesson is that much more opportunity and time are urgently needed to satisfy both the Russians and the British about the facts of thinking and acting on automatic control in the the two countries. The first International Congress of I.F.A.C., which is to be held in Moscow in midsummer, will doubtless repair some of the deficiencies.

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* See CONTROL, Dec. 1959, p. 102 ff.

** *Automatic Control in Soviet Industry*, available from the B.C.A.C., c/o Institution of Electrical Engineers, Savoy Pl., London, W.C.2.

It is not proposed to give here more than a brief review of the three papers that were presented by Professor Ivahnenko during his visit; they merit more detailed treatment than time and space now permit, and it is important to remove as much as possible of the confusion that lingers among those who heard or met the lecturer. This requires study of the extensive bibliography that he quoted, most of it (as one would expect) from work published in his own country, but also covering some thirty publications (mostly American) outside the Soviet Union. Articles on his work, and upon the so-called theory of invariance, are planned to appear in later issues of CONTROL. The theory of invariance was published by Professor G. V. Schipanov in Moscow in 1939, and does not seem to be widely known in Britain, but it was frequently drawn upon by Ivahnenko in his papers.

Before proceeding to the papers themselves, it is worth noting the Professor's estimate that he does not spend more than about a third of his time on administration, for he has staff to relieve him of such duty as far as possible. This is a different situation from the quite common British one, where a man of equal seniority would be fortunate to have more than a third of his time free for purely scientific or technical work. It is perhaps unwise to draw broad conclusions from this one example, but Professor Ivahnenko has been active in his present post in Kiev for less than a decade, and he has been a prolific author of papers, particularly in the last two years. One cannot help noting this in relation to his comparatively light administrative occupation, and suggesting that here is another lesson to learn from his visit.

The three lectures

His three lectures were entitled: **1.** *Principles of the general theory of combined control systems;* **2.** *Combined cybernetic (adaptive and learning) control systems;* **3.** *Applied research in the field of combined control systems of the Automatic Control Laboratory of the Ukrainian S.S.R. Academy of Sciences.* These are the author's translations of the titles, and appeared somewhat differently in use in this country. For example, the second title was quoted as 'Control systems with adaptive and learning features', and the third as 'The work of the Automation Laboratory of the Ukrainian Institute of Electrical Engineering'. The word *cybernetic* was one of several of which the precise meaning in Russian or Ukrainian is not yet established. One Englishman's interpretation, given at Imperial College before the delivery of lecture **2**, was repeated before lecture **1** was read at Northampton College (this oddity of order will be explained in a moment), but the author then objected and said that the significance of the term was quite different. The lecture given at Imperial College was the visitor's first public speaking engagement, and it was only when he began that it became known that the three lectures were prepared for delivery in the order quoted above, with the later ones resting on the earlier ones. Consequently, a hurried treatment of the essentials of lecture **1** had to be given before lecture **2** could be presented. The first of the series was in fact given last in the order of delivery. It would be helpful in future if the usual practice of circulating abstracts or proofs in advance were followed. This, coupled with an adequate allowance of time after the lecture, would improve the standard of discussion. As it was, some useful questions and points were put. Lectures **1** and **2** were delivered twice and lecture **3** once during Ivahnenko's tour.

General theory

The lecture on *Principles of the general theory of combined control systems* concerned the properties of systems which have been the centre of interest at the author's laboratory. The paper began with a remark to the effect that conventional studies of control systems were confined to the behaviour of feedback systems using the 'by-output' (i.e. function-of-output) principle. Combined systems could and often did use feedback control, but they embraced feedforward (i.e. 'open-loop') control—the 'by-disturbances' principle—as well. In passing, the author stated that in some fields of application there had also been extensive study of open-loop control alone. His own work was upon the combination of feedback and feedforward in control systems, and the consequent ability to solve problems which were not satisfactorily soluble by the application of feedback alone. Examples of such problems were:

1. In which systems, by what means, and under what conditions could system error be eliminated? What were the frequency responses of suitable systems? What was the meaning of 'complete error elimination' in physical terms?
2. In arriving at a system completely free from error, was the need for a compromise between system stability and stiffness in the feedback portion removed? In which systems did the need for this compromise vanish?
3. Did the choice of feedforward characteristics interact with the choice of characteristics of the feedback link, and vice versa?
4. If 'complete error elimination' was not practicable, how could error be minimized?
5. In what ratio had feedback output power to be reduced when feedforward was also used?

To answer these questions was to make some progress with aspects of the very general and still unsolved problem: *how does one best choose the elements to manipulate in designing a system for optimum results* (e.g. parameters or non-linearities, structure or codes of impulses)?

The theoretical basis of the general theory of combined control systems was Schipanov's theory of invariance, and even in the author's own country this was not well known.* The theory classified the conditions of stability as they were disclosed by considering the coefficients of the equations of motion. An example of such a class was the state we termed 'conditionally

* It is interesting to note that, according to a report in *Avtomatika* (4, 1959, pp 89-94), a conference on this theory was held recently in Kiev and attended by over 200 delegates.

stable'. The lecturer described types of combined system relative to each class of condition of invariance, which led him to the conclusions that:

(a) Total elimination of error could be achieved, under specified restrictions, by the use of combined systems.

(b) The compromise referred to under **2** above was not eliminated for a particular class of invariance condition called 'absolute' because some system stiffness was required for all disturbances,

(c) The choices of feedforward and feedback characteristics were not interrelated—they were 'orthogonal'—under specified restrictions.

(d) By the application of the theory of invariance, system error could at least be minimized.

(e) Feedback-loop power depended on the efficiency of the feedforward links. When they could be realized, combined systems were more economical in power consumption than other control systems for the same purpose.

(f) Combined systems gave greater flexibility to the designer of automatic controls than did the purely open-loop or closed-loop techniques.

Adaptive and learning systems

Combined cybernetic (adaptive and learning) control systems, the second lecture, was concerned with some theoretical and design work on extremum (i.e. self-optimizing) types of controller for such applications as the regulation of the steam:fuel and air:fuel ratios in steam-raising plant and elsewhere, e.g. in the chemical industry. This work relied on combined-control-system technique as sketched in the first lecture.

There were nine variables of any adaptive system, explained the author, which might be manipulated to give the desired system performance. For such systems, with a single 'figure of merit', there could be ten forms, yielding ninety possibilities. Clearly this number exceeded the bounds of what could be covered in a single address, and it had already been shown in the lecturer's book *Engineering Cybernetics* that each possibility could be realized.

The main point was that combined control systems, as developed theoretically in the first lecture for simpler unadaptive control systems, could with some modifications be applied to adaptive systems, and particularly extremum systems of the kind with only one 'figure of merit' to be optimized. The author set out to establish this point theoretically for the auto-hunting kind of control, and went on to discuss on-off types and cross- and auto-correlated extremum systems when there was noise with the signal. He proceeded next to the relative insensitivity of different systems to noise disturbances, and to the choice of a system for practical use. After dealing with an example of a mining skip-hoist, with extremum control for varying load, friction, and other conditions affecting the motion, he made the point that, for many purposes in industry, unadaptive controls were useless and only extremum systems could be considered.

A variety of methods of providing adaptability in a controller was dealt with by manipulating different variables in unison or separately, and the lecturer illustrated this with a number of examples from furnace control, transport movements, passenger loading, and so on. He ended with some references to the biological models that were suggested by extremum controllers, particularly in complex interconnexions, stating forthrightly that:

> The possibility that man should create the conditions for a complex self-controlled process, thus giving rise to a system more capable of learning than the brain of its creator, cannot be excluded. There is no principle (as in the case of a perpetual-motion machine) which denies this possibility.

All systems of control, no matter how complex, were based on two principles. (*i*) open-loop, and (*ii*) closed-loop techniques. Application of (*i*) required at least some knowledge of the mathematical description of the controlled object, but this was not essential for (*ii*).

Use in industry

The last lecture, *Applied research in the field of combined control systems of the Automatic Control Laboratory of the Ukrainian S.S.R. Academy of Sciences*, was concerned with the application of combined control systems to industrial problems. The first example given was of the advantages of combined control in the steady-state regime for an induction-motor speed control. The motor used a special non-linear rotor in one form, and voltage and current feedbacks were applied to the machine. This made possible speed-ranges of 5:1, obtainable with the low-speed efficiency still about 20% and with the starting torque up to 1·6 times the rated torque. The system had been used in the chemical and textile industries and in furnace stoker drives. Another example was that of a saw-feed speed control in which a stiff response was required. This was obtained by negative feedback of motor voltage and positive feedback of the current of the three-phase machine, without using a tachogenerator. After describing other electric-motor controls, the lecturer dealt with a regulator for the annealing of moving copper wire, cathodic protection of structural metal and pipelines, speed control for river craft, control of the alkalinity of power-station feed-water, control of hydraulic coal-winning equipment, and an excitation regulator for alternators.

To show the use of the advantages of combined controls in the dynamic regime, the author described servomechanisms controlled by derivatives of input, numerical control of a milling machine, and position control of a welding head for joining the seam of metal pipe. In this last example the gain was varied to adapt control. There was considerable use of magnetic amplifiers in the many cases illustrated.

General impression

Whereas the first lecture was compact and well defined in scope, in the second Professor Ivahnenko was dealing with more detailed and complicated aspects, problems of which some were not yet solved. The second lecture was therefore less clear-cut in its message, but it was nevertheless an up-to-date display of the thoughts and problems of the author and his colleagues.

Telecontrol for River Dove Water Scheme

Multiple meter readings and control signals transmitted on four Post Office lines between pumping station and control centre

THE RIVER DOVE WATER SCHEME, officially opened on April 9 this year, has been designed to supply water from an intake on the River Dove to a reservoir some twenty miles away in the Leicester area, and to distribute this water over Leicestershire and Rutland. The functions of four pumping stations incorporated in the scheme are co-ordinated by a comprehensive remote control and telemetering system supplied by Standard Telephones and Cables Ltd.

As shown in Fig. 1, two of the pumping stations and a water treatment plant are situated approximately eight miles from the intake, adjacent to the site of a proposed reservoir.

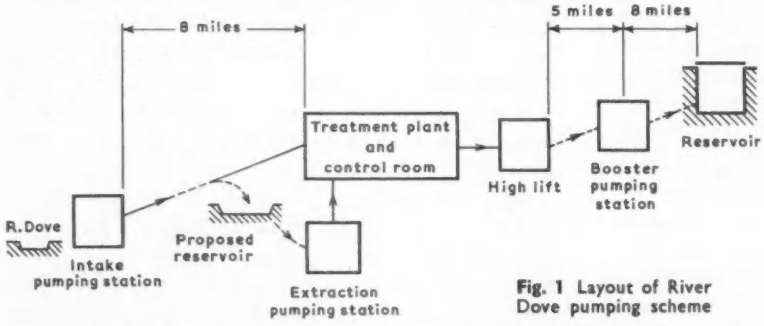


Fig. 1 Layout of River Dove pumping scheme

These two stations are the extraction pumping station, which will ultimately deliver water from the proposed reservoir to the treatment plant, and the high lift pumping station, which delivers from the treatment plant to the outgoing main. At present the scheme is working, at less than its final planned output, with the intake pumps feeding directly to the treatment plant.

The concentration of equipment in the neighbourhood of the treatment plant made it desirable to control the scheme from this point. Standard Telephones and Cables Ltd., designed a telemetering system which presents all the required information from the four pumping stations at a central control desk, from which all the necessary control signals can be transmitted.

Signals to and from the two local pumping stations are transmitted on direct wire systems. The signals for the two remote stations use pulse-modulated signals carried on Post Office lines. For the booster station, the system is relatively simple, and is based on a mains-derived a.c. supply used as a carrier for superimposed control and telemetered information. Signals for this station comprise only a common start/stop control for two pumps and continuous metering of the total water flow.

The arrangements for signalling between the control desk and the intake pumping station are more complex, but nevertheless all signals are carried on two 2-wire P.O. circuits. Outward signals from the pumping station use one pair of lines, and inward control signals use the second pair. Outward signals are of three types: (1) continuous transmissions of the readings of a number of measuring instruments for the flow, level and pressure of water; (2) continuous transmissions of signals giving pump loads and speeds; (3) two-position type signals showing which items of equipment are running, the availability of supplies, and alarm conditions. Fig. 2 shows schematically the numbers and types of signals being transmitted.

Continuous indications

The initial measurements, from which the telemeter signals are derived, originate from various types of measuring elements. Basically, the method of transmission used is to convert each signal to an interrupted tone. The actual value of the measured variable is represented by the rate of interruption, or pulse frequency, of the tone. The true frequency of the tone, which is in the voice frequency range, is peculiar to measurements from a particular measuring instrument, and can thus be recognized by frequency discriminators at the receiving end of the P.O. line. After being 'recognized' by the discriminator, the signal is reconverted to d.c. to operate the appropriate indicator on the control desk.

Pulse rates are classified as either 'fast' or 'slow', the range of the measured variable being represented by pulse frequencies between 0 and 20 per sec. or between 0 and 66⅔ per min. respectively. Both rates are used in this installation. Fast rates require one frequency channel for each signal and give virtually instantaneous response at the receiving instrument, and are consequently preferred for signalling responses to control action at the control desk. Slow pulse-rate signals give a slower response, but if necessary may be made to share a frequency channel. Advantage is taken of this facility for the transmission of level and pressure indications from the intake pumping station, as a slight time-lag in the registration of these variables is of no consequence.

Initial measurements for this part of the telemetering system are obtained from instruments supplied by George Kent Ltd. The variables measured are pumping rate, river and sump levels, and delivery head. At some future date it is proposed to include the measurement of river flow. Besides transmitting to the telemetering equipment, these instruments supply the required local indications, records and summations of the variables. Signals at this stage are d.c. voltages, which are converted to corresponding pulse-rates by S.T.C. Telemeter Sender Units before being transmitted on the appropriate frequency channel.

A typical signalling sequence, that of pumping rate, is illustrated in Fig. 3. The rate of flow is detected as a differential pressure between the pres-

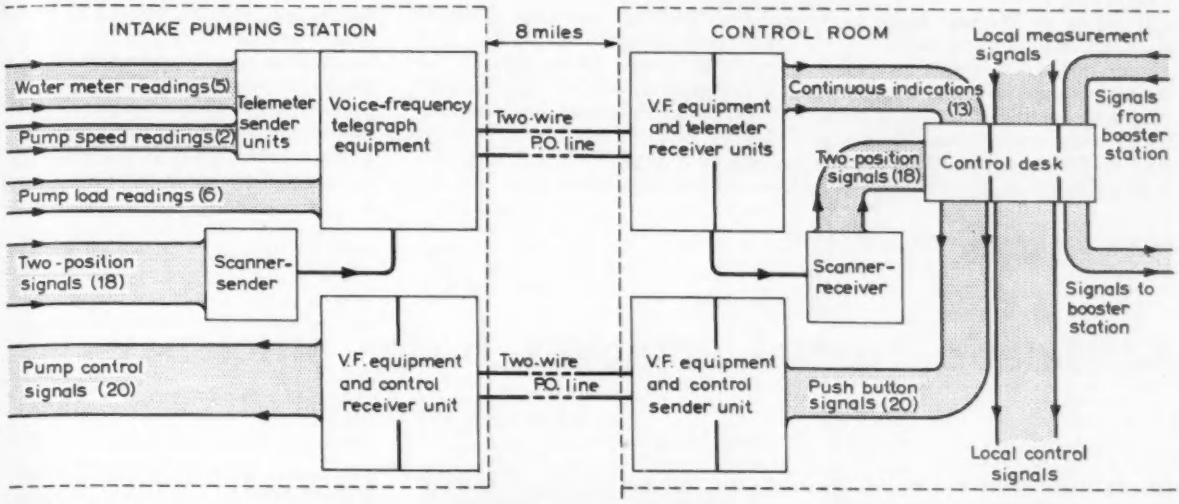


Fig. 2 (above) Block diagram of telemetering equipment between the intake pumping station and the control desk

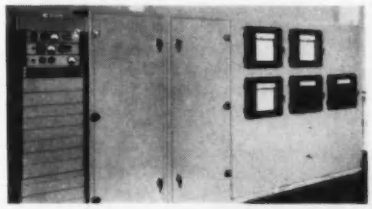
Fig. 4 (left) S.T.C. transmitting equipment, and Kent indicators and recorders, at the intake pumping station

Fig. 5 (below) Control desk at the treatment works

sure tappings of a Kent Dall tube, this differential pressure then being converted to a d.c. signal by a mercury U-tube meter fitted with an electrical transmitter. The d.c. signal operates a recorder/summator on the pumping station instrument panel, and this instrument re-transmits a similar d.c. signal to a fast-rate Telemeter Sender Unit. A pulse-rate in the range 0–20 per sec., and proportional to the rate of flow, is produced, and is impressed on a carrier frequency of 1,140 c/s. This signal is carried on the P.O. line to a frequency discriminator and Telemeter Receiver Unit in the Control Room. The d.c. output from the Telemeter Receiver Unit operates a suitably calibrated milliammeter on the control desk.

Pump signals

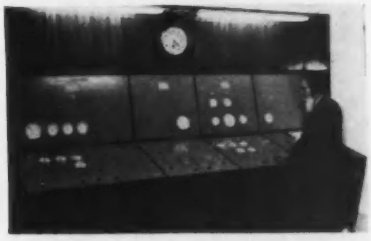
At present the intake pumping station contains one variable-speed and two fixed-speed pumps, all of which are eventually to be duplicated. Continuous indications of load are taken from all three pumps, and a speed indication is taken from the variable-speed pump. The speed indication is



obtained from a tacho-generator, and converted to a pulsating voice-frequency signal in the same way as the water-meter signals. Pump load is measured by Landis & Gyr instruments in series with secondary windings of current transformers in the pump-motor circuits. The current taken by each of these meters drives a slotted disk at a rate proportional to the square of the motor current. A light source and photocell arrangement across the slotted disk produces current pulses at a rate proportional to the motor load. After amplification these pulses are transmitted on individual frequency channels.

Two-position signals

Eighteen indicator lights on the control desk are operated from the intake pumping station via the telemetering system. The lights include on/off indicators for each pump, 'supply available' indicators and various alarms, all operating on a common frequency channel. Indications are transmitted only when a change in one of the indicated conditions occurs, or when a check key at the control desk is operated. If, for example, an incoming supply fails, a normally engaged relay is released and triggers an electro-mechanical scanning switch. This switch scans the eighteen indicated functions in turn. The information is transmitted to the control room in code form, and, after decoding, operates a similar scanning switch distributing signals to the corresponding indicator lights.



Control signals

Signals from the control desk to the intake pumping station are all push-button operated. Twelve frequency channels are used, each capable of signalling two conditions. These conditions are represented by frequencies

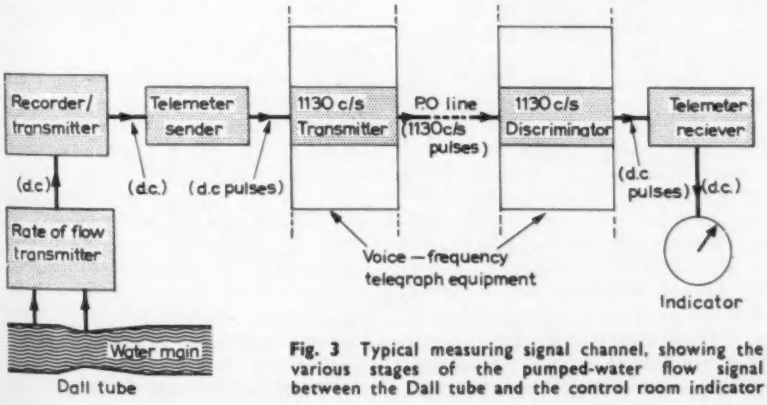


Fig. 3 Typical measuring signal channel, showing the various stages of the pumped-water flow signal between the Dall tube and the control room indicator

differing by ± 30 c/s from the nominal frequency of the channel.

Operation of the push-buttons at the desk changes over the contacts of telegraph-type relays in the Control Sender Unit, and produces the 60-c/s shift in the corresponding channels. Each push-button signal results in a frequency-change on three channels, the combination being peculiar to a particular push-button signal. For speed control of the variable-speed pumps, the 'increase' or 'decrease' control button is held down until the required change of speed is effected.

CONTROL understands from Mr. Hal Wallhouse, Engineer and Chief Executive of the River Dove Water Board, that operational experience indicates that the planning work by his own staff, and the expenditure on the remote control equipment, will be amply repaid in giving maximum control with minimum manpower.

CONTROL IN ACTION

Automatic control improves boiler efficiency

Scottish hospital gets cheaper steam

THE INTRODUCTION OF THE KELVIN Hughes system of automatic boiler control at Strathclyde Hospital, Scotland, has provided an overall increase in boiler efficiency of 6·3%, and steam production costs have been reduced, in spite of a considerable increase in steam demand. With manual control, the ratio of steam generated per pound of coal burnt averaged 8·47 lb, the boilers operating at an average efficiency of 70·4%. With automatic control, however, the average has improved to 9·29 lb, and the efficiency to 76·7%.

The heaviest steam demand is by the hospital laundry; this load tends to be heavy and fluctuating, making the maintenance of optimum steam pressures by manual control most difficult. This sometimes resulted in unsatisfactory laundering, necessitating a repeat of the calendering cycle. Now that steady steam pressures are maintained, this difficulty has been overcome, giving an efficient calendering cycle, and permitting a shorter working period. A reduction of 4% in the cost of steam per pound of clothing laundered is one result of steady steam pressures.

Steam plant

The boilerhouse installation consists of two Ruston and Hornsby 'Thermax' Super Economic boilers rated at 6000 lb/hr at a working pressure of 100 lb/in², fitted with Bennis chain grate stokers. Both forced and induced draught are employed. The water feed, by two Wier pumps each of 8000 lb/hr capacity, is automatically controlled by Ronald Trist boiler-water level controls.

The instrumentation consists of draught gauges, circular-chart recorders for recording flow and pressure, CO_2 indicators, temperature indicators, and strip-chart instruments for recording both CO_2 and temperature.

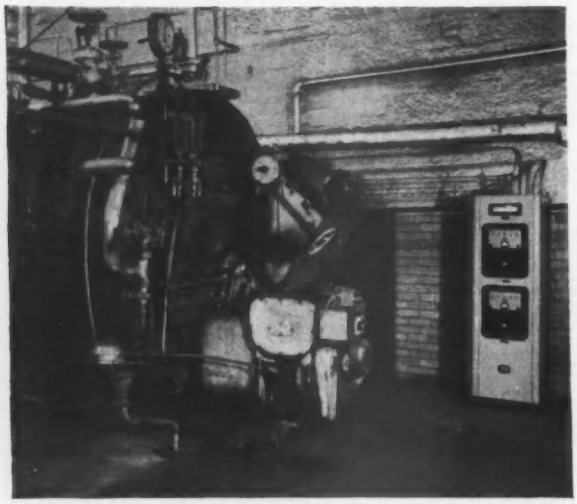
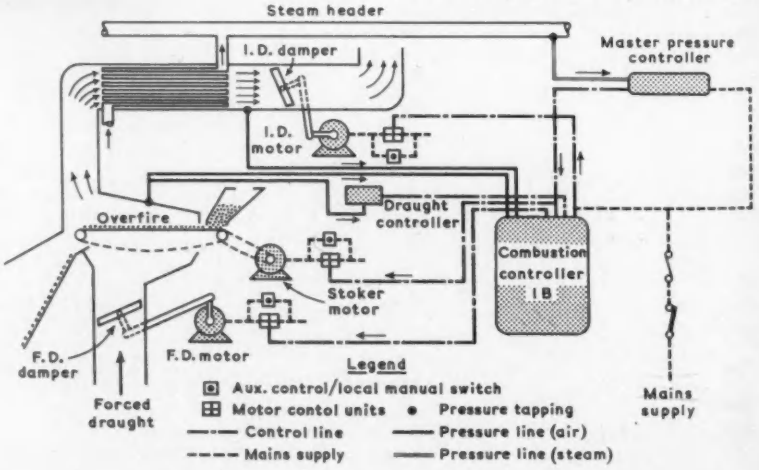


Fig. 1 (left) One of the automatically-controlled boilers with control panel (right) at Strathclyde Hospital

Fig. 2 (below) General arrangement of boiler control-system, showing air-flow control



Automatic control installation

The control equipment comprises a master steam-pressure controller, two combustion controllers and two stoker-speed controllers, these being fitted in a panel on the wall adjacent to the front of the boilers (see Figs. 1 and 2).

Changes in steam pressure are sensed with the aid of a pressure-controller connected to the main steam header and are transmitted as electrical impulses to the combustion controllers which regulate the coal and air feed to each boiler. These impulses position the output shaft of a servo motor.

and this carries twin cams which govern the flow of fuel and air respectively. The stoker motors are d.c. operated, and are regulated by a feedback from the armature, so forming the closed loop speed control shown diagrammatically in Fig. 3.

Airflow control is complicated by the necessity for maintaining a pressure slightly lower than atmospheric in the combustion chamber. This is done by so phasing the damper operations that the induced-draught damper leads the forced-draught damper on increasing loads. Under conditions of increasing heat-demand, a step-by-step cycle of damper adjustment is initiated, the induced- and forced-draught dampers being operated intermittently until the system balances.

Conversely, on a decreasing heat-demand, the forced-draught damper operates first. Adjustment of the dampers over the full range of draught takes 30 seconds.

Switches on the combustion controllers enable the operator to change over to manual control when removing ash, or starting up or shutting down a boiler. The controllers are adjusted so that the boilers share the load: this was done on initial commissioning and no further adjustment should be necessary.

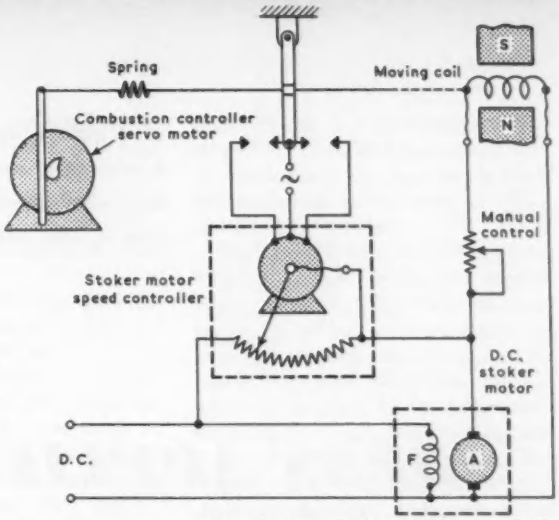


Fig. 3 Feedback from the armature provides closed-loop speed-control of stoker motor

Operational analysis

The coal, which is obtained locally and is known as 'Woodhall Dross', costs on average £4 12s. a ton, and has a nett calorific value of about 12,780 B.t.u./lb.

Over a period of seven months (June to December) the figures for manual operation were: water evaporated per pound of fuel, 8·47 lb; boiler efficiency, 70·4%.

Over a corresponding seven-month period in the following year the figures for automatic operation were: water evaporated per pound of fuel, 9·29 lb; boiler efficiency, 76·7%.

The use of automatic control has thus increased the efficiency of the boilers by 6·3%, and fuel savings over the seven months amounted to about 101 tons. At £4 12s. a ton, this represents a saving of £464 12s. over this period — approximately half the cost of the control installation.

In addition to this saving, the servicing of steam mains (comprising about a mile in total length) has been negligible. This is due to the maintenance of a constant steam pressure, and the elimination of water hammer in the steam mains. Furthermore, during the period of automatic operation the average steam-load on the boiler-house was increased by 600 lb/h.

CONTROL IN ACTION

Remote control at Royston oil depot

A RECENTLY-COMMISSIONED SHELL-MEX and B.P. storage depot at Royston, Hertfordshire, employs remote control to a greater extent than any previous similar installation in this country. The installation includes a control and indication system, by Evershed and Vignoles, which allows routine operations to be carried out from a control station adjacent to the tank compound, with over-riding control from a remote panel in the manager's office. The remote panel, which is some 300 ft from the compound, incorporates a mimic diagram with indicators and warning lights which give an overall picture of conditions in the tank compound at any time.

The function of the depot is to provide storage for a variety of fuels and lubricating oils, delivered by rail and awaiting local distribution by road. Ten tanks, which are used for fuels only, are served by the Evershed control system.

The operation involves filling from railcars and supplying road tankers. For filling, a pump and inlet valve for each tank are operated from the local control station. These operations are indicated on the remote panel by lights, and, if necessary, an over-riding signal may be sent from the panel to close the inlet valve. The level of the fuel in each tank is continuously indicated at the remote panel, and both visual and audible alarms are given if the level approaches its upper limit. The visual alarm is a flashing light on the panel. This, and the audible alarm, may be cancelled manually, but a continuous light remains on until the alarm condition is cleared.

The quantities to be supplied to individual road tankers are pre-set on Wayne positive-displacement type meters. These meters incorporate an automatic valve which cuts off the flow progressively as the pre-set quantity is approached, so avoiding hydraulic shock. Printed tickets for each operation, showing the quantity passed, are also provided by the Wayne meters. Outlet pumps are controlled from the local station, and master outlet valves from the remote panel. Both these and the inlet valves are electro-pneumatically operated.

Remote indications

Continuous indications of the level and average temperature of the fuel in each tank are given at the remote panel. These measurements are obtained from Evershed precise tank gauges and average temperature gauges respectively.

In addition to these continuous indications, lights on the remote panel show the positions of the inlet and master-outlet valves, and which pumps are running.

CONTROL understands that, although this installation might be considered only as an intermediate stage in the development of a fully-centralized control system, it has proved to be very satisfactory in practice.

A monthly review—under basic headings—of the latest control engineering developments for all industries; specially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are not specialized in instrument and control systems

IDEAS APPLIED . . .

. . . to TEMPERATURE

Refinements in two-step control technique

Two difficulties associated with direct-deflexion type temperature indicators used for two-step control are (1) lack of power in the meter movement to operate control-circuit contacts and (2) excessive hunting caused (as with any other two-step control) by time-lag in the response of the plant.

Interesting features are incorporated in Metrix Instruments' new 'Metrawatt' indicator-controller to deal with these difficulties.

Control action is initiated by a small aluminium flag on the measuring pointer which, at the control point, enters the air-gap between the coils of an oscillator circuit. This action brings about the action of the on/off control relay by means of the circuit shown diagrammatically in Fig. 1. When the flag enters the air-gap, oscillation is interrupted and excitation of the transformer in the transistor circuit ceases. The coil of the control relay, which is in series with the secondary of the transformer and a rectifier, is thus de-energized.

This sequence of operations is reversed when the flag leaves the air-gap. The control action is thus achieved without mechanical complication or load on the instrument movement.

The effects of plant lag may be diminished by the thermal feedback system illustrated in Fig. 2. The principle of the system is that the time at which the 'on' or 'off' action is initiated is advanced by feeding a small e.m.f. into the measuring circuit in series with the thermocouple. During the part of the cycle in which the temperature is above control point, the injected e.m.f. is in opposition to

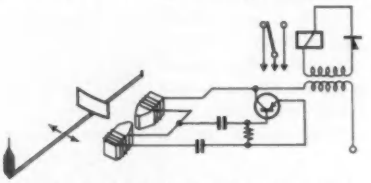


Fig. 1 Method of initiating the control action

the e.m.f. of the measuring thermocouple. The value of the injected e.m.f. increases steadily with time from the time at which the control action reduces or switches off the heating power to the plant. The effect of this e.m.f.

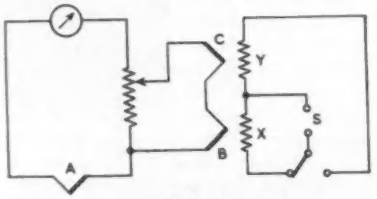


Fig. 2 Thermal feedback circuit to reduce effects of plant lag

is to advance the time at which the power is again switched on. A similar injected e.m.f., but assisting the thermocouple e.m.f., advances the control action on the half of the cycle when the temperature is below control point.

The thermal feedback circuit used to inject the correcting e.m.f. consists essentially of the two thermocouples B and C, their respective heating elements X and Y, and contacts on the main control relay arranged to energize these heating elements in turn. When the temperature is above control point, current is taken by the heating coil X. An e.m.f., increasing with time and opposing that of the measuring thermocouple A, is generated by thermocouple B. The result is to return the measuring pointer to the control point ahead of the true temperature, and advance the time at which the plant heating supply is switched on. A shunt resistance controls the amount of feed-back, and has to be adjusted to suit the plant.

A criticism of the system might be that movement of the measuring pointer by injecting an e.m.f. means that the true temperature fluctuations are not accurately indicated. This is possibly not important where the prime function of the instrument is to provide close control.

. . . to LEVEL

Determination by hunting probe

An accuracy of the order of 0·001% of full scale reading, in one application, is claimed for a liquid-level detecting device for which the U.K.A.E.A. holds patent rights.

The principle of the equipment is to cause a probe, which is remotely positioned by a d.c. motor, to approach and finally contact the liquid surface. Contact with the surface completes a circuit which reverses the d.c. motor, and hence the direction of motion of the probe. When contact with the surface is broken, the motion is again reversed, and the probe continually hunts about a mean position representing the true level of the liquid. The

response of the circuit used is such that the amplitude of the oscillations is only a few thousandths of an inch. The motion of the probe can therefore be transmitted, via a damping device, to a dial indicator giving an accurate level reading.

The main components are the probe, comprising a platinum point contact suspended from a stainless steel wire wound on a drum, a thyratron, and a split-field d.c. motor. With the probe out of the liquid, operation is started by a manual switch energizing one section of the motor field. The probe is driven into the liquid. On making contact, a circuit is completed which fires the thyratron, and energizes the second section of the field. This field section opposes the first section and carries double the current, so that rotation of the motor is reversed. The probe is raised clear of the liquid, and the whole sequence repeats.

The indicator is driven from the rotating drum, and is geared to make complete revolutions for relatively small level changes, a second dial giving the number of revolutions.

The method is almost independent of the nature of the liquid. It is sufficiently sensitive to be used with demineralized water, which is not normally regarded as a conductor. A total resistance between the contact and earth of up to 20 MΩ can be tolerated.

A possible application might be to provide fine control in water-moderated reactors, where the power level depends on the depth of water in the core.

. . . to SIZE

Thickness inferred from speed

A method of measuring the reduction in thickness of steel strip passing through rollers has been developed by B.I.S.R.A. It depends on a comparison between the speed of the strip before and after rolling, the speeds being inversely proportional to the respective thicknesses. Relying on a photoelectric principle for the measurement of the speed, the method has the advantage that there is no physical contact between the measuring device and the strip.

Two photocells are sighted on two illuminated spots on the strip at a known distance apart, the spot centres being on a line parallel to the direction of motion of the strip. Small irregularities in the light reflected from the strip surface give rise to a certain pattern in the output of the first photocells. After an interval of time, depending on the speed of the strip, a similar pattern appears in the second photocell output.

In order to find the time interval between the occurrence of the pattern on the two outputs, the output of the first photocell is delayed, on a tape recorder or otherwise, and added to the second output. The time delay is then varied until the combined output is a maximum, which will occur when the patterns coincide. The known delay time is equal to the time taken by the strip to travel the distance between the two light spots. By this means the speed on one or both sides of the rolls can be calculated, and the thickness ratio determined.

. . . to PRESSURE

Accurate remote pressure indication

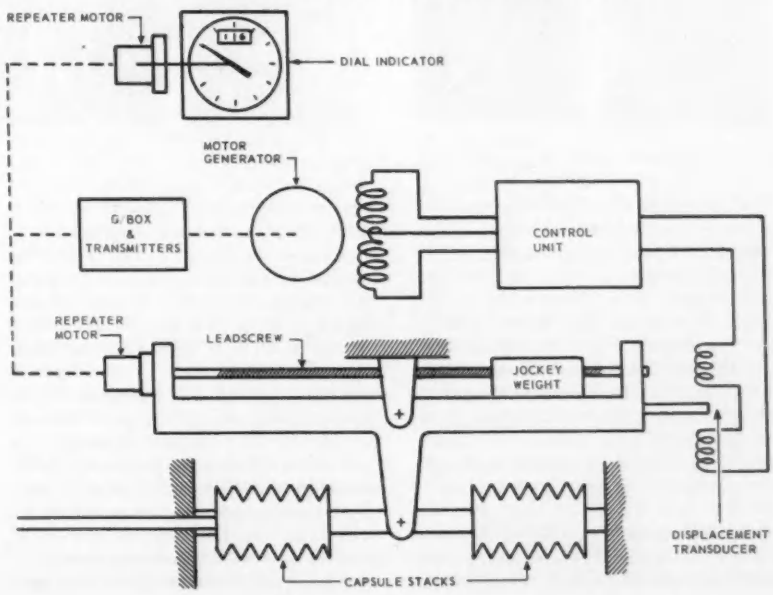
Electrical remote indication of signals from pressure-sensitive measuring elements is commonly obtained by balancing a mechanical force derived from the element against an electromagnetic force derived from the signal current. A device produced by B.P.A. Electronics balances the force of the pressure-sensitive element against the mechanical moment of a weigh-beam. The position of an adjustable weight on the beam is set by an electrical servo-system. The servo-system also positions one or more remote indicators, and it is claimed that signals may be transmitted by this arrangement with accuracies of the order of 0·02% of full scale deflexion.

The pressure differential being measured is applied to the two capsule stacks, shown in Fig. 1, and displaces the weigh-beam. For measurement of absolute pressure, one of the stacks is evacuated and sealed. The displacement is detected by a differential-transformer displacement-transducer mounted at one end of the beam. The output from this transducer corresponds in phase and magnitude to the displacement. This signal is fed to a control unit, consisting of an amplifier and a phase-conscious rectifier, which controls a split-field motor-generator. A transmitter driven from the motor-generator operates repeater motors on the weigh-beam and on the remote indicators.

The repeater on the weigh-beam is geared to the leadscrew which carries the balance weight, and drives the weight in the appropriate direction to restore balance. The travel of the weight, and hence the number of revolutions of both repeater motors, is directly proportional to the pressure difference registered by the two capsule stacks.

Emphasis in this design has been on accuracy rather than response time. Applications are expected to be mostly in research, in such fields as turbine engineering and wind tunnels.

Fig. 1 Schematic diagram of pressure transmission system



PEOPLE IN CONTROL *by Staffman*

The reorganization of the Smiths-Kelvin Hughes group continues apace. **G. B. G. Potter,** Managing Director of Smiths Aviation, Marine and Industrial Divisions, will now further concern himself with the direction of the collective research and engineering facilities of the Division. I gather that the idea is to bring the various resources of the several Divisions under one authority, the better to co-ordinate aviation systems engineering and the more complex instrument projects. **K. Fearnside** becomes Director of Research and Engineering of Smiths Aircraft Instruments, and is directly responsible to Potter for that company. **G. G. Roberts,** who remains Technical Director of Smiths Aircraft Instruments, will assist Fearnside in his new appointment. These changes apart, the companies will function as before.

POTTER
research

McGLYN
quality

H. McGlyn, who has been appointed quality control engineer at West Instrument's Brighton factory, is the representative of the Engineering Equipment Users' Association on the B.S.I. Committee for the graduation of instruments. An ex-Ministry of Supply and I.C.I. man, he was at the latter's Central Instrument Laboratory, Pangbourne, concerned with the development of special equipment for experiments in automatic control and with the evaluation of instruments.

Semiconductors' new Chief Applications Engineer is **J. W. Ringrose** who will take charge of their Applications Laboratory which is being expanded. Ringrose was seconded from the British Rayon Research Association to Birkbeck College, London, to work on electronic digital computers. He joined Plessey as a Senior Development Engineer in 1951, and worked on digital systems, computers and commercial data-processing problems. Latterly he has become more and more concerned with the application of transistors.

P. A. Charman, who has been appointed Sales Development Manager of Semiconductors, will, I gather, be responsible principally for dealing with the technical aspects of customers' needs, especially in their long-range planning.

I was interested to hear of the election of **M. L. Jofeh,** Manager of

RINGROSE
application

FALKNER
sales

Sperry Gyroscope's Industrial Division, as an additional Director of the company. Jofeh joined Sperry in 1947 as an Equipment Engineer, and headed the engineering unit at Sperry's Stonehouse (Glos.) factory for a number of years. In early 1954 he returned to Brentford as Deputy Chief Engineer and later became Chief Engineer with responsibility for the design of all new equipment. He became Manager of the newly-formed Industrial Division in January 1959, when Sperry disclosed plans covering the extension of activities into the field of industrial control systems and instrumentation.

Appointed General Sales Manager of Sperry Gyroscope's Brentford Division, **R. I. T. Falkner,** has a special responsibility for marine and aircraft equipment. An ex-member of the Royal Navy—he has a master's ticket—Falkner has been concerned with navigational aids and communications, and has been with E.M.I., Pye and Plessey. He tells me that the ultimate in marine automation must be that the master of a vessel should have complete control from the bridge, all relevant navigational and other data being presented to him at that point.

OFFORD

WILLSHER
on the board

Having joined Honeywell Controls in 1949 and been successively, Joint Works Manager, Works Manager and General Manager of Honeywell's Newhouse (Lanarkshire) factory, **C. H. Offord** has been made a director of the company. A member of both the Society of Instrument Technology and the Instrument Society of America, he has served on several S.I.T. committees.

John F. Willsher, Works Manager of George Kent, who has recently been appointed to the Company's Board, tells me that much of their forward thinking nowadays is devoted to electronics, although pneumatics can by no means be dismissed as of negligible importance. He feels that the decision whether to use electrical, pneumatic or a combined system depends entirely upon the nature of the job. 'The modern trend towards electronics does, however, give rise to the problem: where are the new skills required to maintain these black boxes coming from?'

The Editor tells me that he was highly delighted by **Stafford Beer's** crackling lecture on 'Automation and Uncertainty' before the British Computer Society last month. Beer, who is head of Operational Research and Cybernetics at United Steel Companies Ltd., has gone to Illinois University for a Symposium on organizing systems sponsored by the U.S. Navy Department. Only thirty world experts have been invited to this Symposium.

'Instrumentation has got to be brought down to earth' according to

L. W. (Laurie) Farey, who is now senior instrument engineer in the Engineering Division of Mobil Oil's Coryton refinery. Farey's ex-chief, **R. G. Hill,** has taken up a similar position with Esso Petroleum at Fawley. Farey tells me that he feels strongly that 'every installation must be judged on its economic merits alone and this applies to computation as well as to conventional control'.

I hear from **H. M. Whitcombe,** Sales Director of R. B. Pullin, that his Board have agreed to strengthen his sales force. **J. R. Turrill,** who is now General Sales Manager directly responsible to Whitcombe, will have four specialist sales managers under him: **I. H. M. Campbell,** motors and servo components; **R. W. Jelbart,** thermostats; **A. Wolstencroft,** sub-contracts and special products; **G. B. Jeffery** (Technical Manager), control systems.

A. J. P. Martin is no longer Director of Research of Griffin and George, having expressed to the Chairman of the group, **K. G. Sinclair,** his desire to concentrate in future primarily on fundamental research work. Martin's deputy **R. C. Palmer** succeeds him as Director of Research. I gather, however, that Martin will in future act as Consultant to the G. & G. Group.

I hear from **R. W. Pringle,** Chairman of Nuclear Enterprises (G.B.), that **Ronald S. Stiff** has joined them as Sales Manager. This appointment is part of the company's plan to quadruple its size during the next two or three years. Pringle tells me that he intends touring the U.S.A., and that Stiff will make a similar tour of Europe later in the year. Stiff was with Ferranti for twelve years and, more recently, with Bruce Peebles as Chief of Sales, Electronics Division.

AUTHORS IN CONTROL

Basil Clarke (*Polaris fired*, page 139) saw the first underwater firing tests of Polaris in the Atlantic. He has been an aviation journalist and broadcaster since 1932 and wrote, *inter alia*, 'Atlantic Adventure' (Allan Wingate, 1958), the first complete history of Atlantic flying. He is now working on a history of airships for Herbert Jenkins, which accounts for his presence in a U.S. Navy 'blimp' during the Polaris tests. Clarke is also Deputy Editor of *Machine Age*, one of CONTROL's sister publications, which will first appear in June.

D. K. Hill (*Automating the glass industry*, page 140) was educated at Bingley (Yorks) Grammar School and the University of Manchester where he obtained his first degree in 1938 and Diploma in Education in 1939. He then joined H.M. Forces, serving with R.A.O.C. and R.E.M.E. on radar and telecommunications. Later, with the Ministry of Supply, he studied the behaviour of electronic equipment and

HILL

components under a variety of conditions. He was appointed lecturer in the Dept. of Glass Technology, Sheffield University in 1947 and obtained the degree of Ph.D., as a result of work on the optical absorption and magneto-chemical behaviour of a group of unusual glasses. When the glass industry formed its own research association in 1955 he was appointed Deputy Director. Dr. Hill is interested in both fundamental work on glass as a material and applied research in industry. In the last connexion he has worked on the application of instruments and controls to different aspects of the very complex processes used in glass making and shaping.

R. A. Morley (co-author with M. B. Wood of *Computer process control*, page 144) graduated in mathematics

MORLEY

from Cambridge University after wartime service in the Far East. He then spent five years on servo and general system studies with Bristol Aircraft before joining the Wythenshawe (Manchester) department of Ferranti in 1955. There, he has worked on guided weapon systems, and is now responsible for the industrial applications of the Argus digital process control computer.

D. H. Roberts (*Solid state relays and switches*, page 153) graduated in physics from Manchester University in 1953 and then joined Plessey's Caswell Research Laboratories. He is now with the same company, engaged on semi-conductor research as Group Leader of the materials and devices section. Previous work has been concerned with indium-antimonide infrared detectors and Hall effect devices.

G. M. E. Williams (*Back and forward*, page 163) describes himself as being 'in the early forties but well preserved, and preceded on the paternal side by four generations of instrument makers.' He graduated at London in physics and mathematics. His first job was concerned with insulation in heavy electrical engineering, but this was interrupted by the war. After the war he was with the Government Scientific Service until 1955, when he joined the Technical Division of the Production Engineering Group. Four years later he was appointed to his present post as Head of the Department of Production Technology and Control Engineering at the Northampton College of Advanced Technology.

N. G. Meadows (*Graphical techniques for control systems*, page 179) studied part-time at Bristol College of Technology while employed by the Admiralty as a design draughtsman on fire-control projects. A full time course in Technical Teaching at Garnett College followed, qualifying him for a lectureship in Power Engineering at Twickenham Technical College from 1952 to 1955. He then entered industry as a patents engineer, and carried out technical liaison between the head office and works of Redifon, being concerned with flight simulators and electronic controls. Leaving Redifon in 1956, Meadows took up his present post at Wimbledon Technical College, where he has been largely responsible for the initiation and organization of courses for N.H.C. students and graduates in control systems and analogue computers.

Pick-off

by 'UNCONTROLLED'

CONTROL has played its part in drawing attention to Soviet progress in the field of automation, but there is a danger that the lay public—and some technical men—will be propelled by Russian rockets into an exaggerated awe of Russian ability everywhere. Over Easter I saw in one of the popular dailies a prominently displayed front-page story quoting the latest scientific revelation from *Pravda*. 'By rocket into the next century,' announced the headline, but it was only the celebrated clock paradox of Einstein all over again, dressed up in space travelling clothes. While we should give proper credit to achievement, there is no call to regard the Russians as scientific supermen. I have heard first-hand reports in the last few weeks, for example, indicating that the Soviets are well to the rear in computery. On the other hand, they are shooting ahead in mechanical translation.

BRITISH manufacturing industry spent about £300m on research and development in 1958, compared with about £190m in 1955. I read this estimate in a D.S.I.R. survey, *Industrial Research and Development Expenditure 1958*, published last month. The outlay represents 4·2% of manufacturing industry's contribution to national production, compared with 3·1% in 1955. 95% of the £300m was spent in industry's own establishments, and about 5% was paid to outside bodies such as co-operative research associations, universities and other public and private research institutions. The main expenditure was in aircraft (£100m), electrical engineering (£64m) and chemicals (£43m).

These figures are based on the distribution of qualified r. & d. men as estimated from an M.L.N.S. survey in January 1959. The D.S.I.R. has tried to discover how the cost of employing a qualified worker on research and development has changed since 1955. The Department's findings, described in the report, show (not very surprisingly) that this cost varies greatly from one industry to another. The average cost of a qualified worker for all manufacturing industry was nearly £11,000. In the case of the aircraft industry the figure was nearly £31,000 and the average for manufacturing industry other than aircraft was just under £8000. In 1955 the cost of a qualified worker was £5600, an increase of 43%, of which 14 or 15% can be attributed to rising prices and incomes. It is interesting to compare these figures with the one given at a recent I.Mech.E. meeting (see pp. 102–104 of last month's issue); it was said there that an engineer to-day needs £1000 spent on him every year—for things like computers—to make his work productive.

ELSEWHERE in this issue one of my colleagues reports last month's I.E.E. Symposium on air-traffic control. The usual battle seems to have flared up between those who fear and those who favour control by computer. In another article this month (Morley and Wood) I see a reference to computers as a means of easing congestion in road traffic. For my part, I think that the inefficiency of

transport has risen so much that the country simply *must* cut through to a solution quickly. That means that we can't afford to rely only on radical measures like rubbing out existing roads and starting again, or building vast new airports all over the place. Automation in the handling of travellers is as necessary as in the handling of other materials, and computers will certainly be called for at some stage in the game. Certainly machines are liable to make mistakes and to break down, but so are human beings, and we have probably reached the cross-over position at which the fallibility of the man is the greater.

Not completely on the point, but perhaps not quite irrelevantly, I am reminded of a recent visit I paid to an unfamiliar part of London. Walking along a side street I came to a road junction. Two signs greeted me, one on the roadway and the other on a post beside it. The notices were brief and free of excessive verbiage, as road signs should be. *No exit*, said one; *No entry*, added the other. I suppose computers could be just as silly as this, but somehow I think I should resent it less than if responsible human beings were at fault.

SOME months ago I reported a significant new non-dimensional number—the coefficient of accessibilitance. This, readers may remember, is the ratio of actual-to-ideal accessibility of knowledge in a community. I was led to think about this sort of thing again the other day when I had to go into a book shop to buy a child's gift. This done, I found myself browsing among the technical shelves, and toying with the idea of buying. Suddenly I was struck with an oddity of my own (and perhaps some other people's) psychology.

A technical journalist's is a mixed lot, but one advantage he does theoretically have; that is, the possibility of seeing new books before they are passed to reviewers. With the lapse of years, however, he tends to become oblivious of the stream of literature swirling past: there is so much of it! In fits of enthusiasm he tries sampling techniques, but he soon loses hope of keeping pace with everybody. It is of course impossible to cover completely a broad band in to-day's technological spectrum. The specialist's life is easier in this respect because, with his small frequency-range, he can keep abreast of most of the published information. In principle, I agree that total specialization is an evil thing, but it is becoming harder and harder to avoid. General reading in leisure hours (supposing them to exist) is the usual specific, and I suppose that some such prescription in my subconscious mind made me want to buy in a book shop what I would probably have left unopened in the office.

NEWS ROUND-UP

from the world of control

MISSILES

Blue Streak abandoned

The British i.r.b.m., Blue Streak, has been abandoned officially, and apart from some slight chance of its use as a space vehicle, and a much greater chance of its use as a political weapon, we should hear little more of this ill-starred, if militarily-justified, programme. This will be a bitter blow to the teams built up by the commercial firms involved in the development of the project, and it is to be hoped that the greatest efforts will be made to keep these teams in being; once dispersed, the individuals concerned will be wary of government contracts and, it has been suggested, even consider seriously the superior status that the scientist and technologist is supposed to have beyond our borders.

Why?

The reasons for the decision to abandon the British ballistic missile are fairly obvious and, we would suggest, connected mainly with cost. The project has to date cost £65m, a figure that may well increase to £100m, or more, before the taxpayer has finally finished with his commitment. In all, at least £500m would have been necessary before we had an efficient weapon.

The military reasons for its abandonment are not quite so simple. It is a liquid-fuelled device, with all the tactical problems inherent in such a design, and it needed 'hard' bases. Recent military thinking appears to be to the effect that even hard bases would be vulnerable to a saturation nuclear attack. Yet another reason suggested, is that the operational life of the V-bomber force has been extended by the development of improved navigational and jamming systems, so providing time for a successor to Blue Streak to come into being.

What next?

With Blue Streak discarded, the V-bomber force must carry the nuclear responsibility until the next stage. Blue Steel, the Avro stand-off, or powered-bomb, although not yet operational, is expected to take over until the Americans are able to let us have Skybolt. The latter is an aircraft-launched two-stage ballistic missile of some 1000 miles range—it is said—which is expected to go into (American) service in late 1964. The U.S. State Department has, in fact, said 'It is our understanding that the need by the United Kingdom is not immediately urgent. . . .' On the face of things, Skybolt does appear to be the most suitable weapon from the economic standpoint, and militarily unexceptionable. The fact that it is air-launched is also in its favour, for suitable launching aircraft exist at present. Furthermore, if it becomes necessary to develop new aircraft to carry the weapon, this may well be, of itself, in the national interest. A combined transport-bomber could have potentialities in the civil field.

The alternative to Skybolt is also American. This is Polaris, the submarine-launched missile Basil Clarke discusses on page 139 of this issue. This weapon is in many respects preferable to Skybolt, and is certainly in a far more advanced stage of development. However, the costs of the nuclear-powered (or even conventionally-powered) submarines necessary for the proper deployment of Polaris would appear to place it out of court.

The navigational problems are also formidable, although presumably these have been overcome.

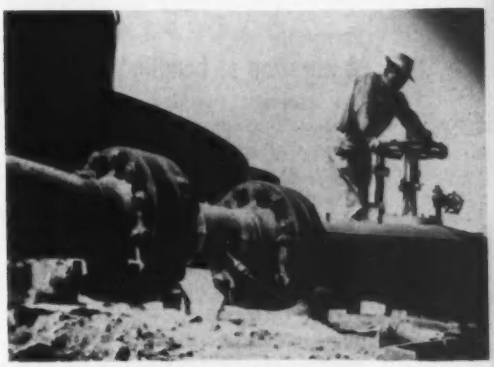
It need not, of course, be submarine-fired but no other method of launching—ship, for example—can provide the essential mobility and security which we are persuaded is so necessary in nuclear warfare.

FLOW

D.H. Props make Pottermeter

The Pottermeter, a 'bearing-less' flowmeter developed by the Potter Aeronautical Co. of Union, New Jersey, is now being manufactured and marketed by de Havilland Propellers, and CONTROL saw the device demonstrated at Hatfield recently. This proved quite impressive, the device certainly appearing to do all that is claimed for it. The unusual feature of the Pottermeter is that its rotor is forced upstream against the flow being measured, so that there is little or no friction and, in fact, no thrust bearing. A venturi effect creates a differential pressure across the rotor, which acts in opposition to the thrust caused by the flow.

The Pottermeter is a by-product of missile research, and was briefly described by M. A. Perry in *Transducers for g.w. research* (CONTROL, May 1959). The inventor is said to have conceived the idea while watching a fish stationary in a fast-running stream. The de Havilland Propeller company's interest in the device stems from their requirement for a flowmeter capable of handling the noxious liquids used as fuel by their ill-fated Blue Streak. They approached their U.S. friends, Convair, and were recommended to use Mr. Potter's flowmeter. The present manufacturing-licence arrangement grew out of this use of the instrument by de Havilland.



A 6-in. Pottermeter installed in the Sun pipeline installation at Port Newark, U.S.A.

MOTOR CARS

Quenching at Dagenham

In the heat treatment of crown wheels and other gear parts at the Ford Motor Co., Dagenham, control of the quenching action on twelve Gleason machines is now performed automatically by Honeywell Electronik controllers, and the primary sensing element is their Radiamatic compensated radiation detector. The detectors are fitted vertically on the upper part of machine, the lens focusing radiant energy from the work-piece on to a radial assembly of thermocouples connected in series.

A distant continuous-balance controller is associated with each detector. Immediately the work-piece is placed in the machine, the scale reading rises to about 1550°F; the scale reading falls as the work-piece cools to about 1510°F; a contact in the instrument then causes the work-piece to be moved horizontally and the machine cycle begins. The press cannot operate if a gear below quenching temperature is inserted.

The three oil valves on the Gleason machine give oil flows on a 16 in. machine varying from 40 gal/min to 210 gal/min; on the 26 in. machines the flow varies from 50 to 300 gal/min. Once the controller has initiated the machine cycle, the timing is carried out within the machine. According to Honeywell, these quench presses provide consistent quality 24 hours a day, and guarantee distortion-free operation, so eliminating scrap.

MATERIALS

A question of handling

At a recent two-day conference on materials handling at Willesden Technical College under the auspices of the Willesden and Hendon Productivity Committee and the Institute of Materials Handing, the feeling emerged that if a mechanical handling system were contemplated, the manufacturing process must be viewed in its entirety. C. G. Chantrill (C. G. Chantrill & Partners) emphasized this point, saying that any production process begins with the supply of raw materials, and ends only when the purchaser is in possession of the finished article. Martin Brown (S.P.D. Ltd.) said that the first consideration must be an analysis of existing handling costs, which must extend backwards and forwards from the area directly under consideration, since any change in a given part of a handling system may reflect changes throughout the whole process. In the same vein, C. H. Manners (Metal Box) suggested that the first questions to be asked should be what? why? where? when? and how? in other words the 'how?' (i.e. what equipment is necessary?) should be the final decision at the end of a full and complete investigation of the overall problem. E. J. Thomas (A.E.C.) remarked that if mechanical handling succeeds in speeding production, then electronic data-processing may become essential to keep information in step with production.

DATA PROCESSING

Computers galore

As ever, computation and data handling could easily form the bulk of these columns this month, information having been released on Ferranti's air traffic control computer Apollo, R.A.E.'s digital differential analyser, Corsair, the L.C.C.'s Eric (an IBM 650), and an A.E.I. 955 analogue computer for Ford, to mention but a few items.

Apollo for a.t.c.

Ferranti's Apollo computer, the first of its type ever to be used for air traffic control experiments in this country, will go into operation at the Scottish air traffic control centre at Redbrae, Prestwick, early in the spring of next year. (See *An unsolved problem*, page 182). Apollo, a high-speed, transistorized, parallel computer, will be used initially for processing flight information on an experimental basis.

The Ministry of Aviation approached Ferranti for a computer with which to experiment in order to investigate the more efficient use of airspace by new air traffic control techniques and the use of smaller separation standards. Furthermore, the use of a computer should free the controller from a number of time-consuming routine tasks.

The computer will print-out flight-progress strips relating to each aircraft, and provide up-to-the-minute information on air traffic conditions. It will also determine whether aircraft are in conflict and, if it is found that separation standards are being infringed, details of this will be printed out for the controller. The complete situation may also be shown pictorially to the controller.

For processing flight information, the computer receives data from the local operators via four Creed 75 printers with keyboards. The information will be sorted out in conjunction with the controller, and relevant information will be passed to the buffer store of the computer. Simultaneously, a record of what has been typed appears on the printer associated with the keyboard, and, if the operator is satisfied, he presses a key on the keyboard to cause the computer to transfer the information into the main file.

Depending on the message, certain stored programmes are brought into action and data are processed and checked for conflict. If the information concerns a flight plan it is stored until the departure time is received. This information is then processed and flight-progress strips are printed out automatically on Creed 75 printers. This is done according to a time criterion, so that the strips may be entered on a board in readiness for the entrance of an aircraft into the controlled area.

Apollo incorporates a time-sharing facility which ensures that it can always be fully engaged even while peripheral transfers are taking place. Although operational programmes have priority, the computer can also be used for carrying out routine calculations and developing programmes.

. . . and for U.S. a.t.c.

An electronic computer for handling air traffic control problems began tests at the U.S. Federal Aviation Agency's Experimental Centre in Atlantic City, New Jersey, on April 25.

Designed and built by General Precision Inc. for the F.A.A., the installation will provide a complete data-processing system capable of processing and printing, 1600 flight-progress strips and processing 440 aircraft flight plans in an hour. It can store a total of 1000 different aircraft-flight plans, and will be able to sequence the arrival or monitor the departure of 90 aircraft an hour.

London's Eric

The L.C.C. have installed Eric—electronic recording and integrating computer (or 'electronic replacement for innumerable clerks')—an I.B.M. 650 electronic data-processing system, at County Hall. Initially, Eric will be concerned with such large, repetitive, routine, clerical, time-consuming but essential, accounting tasks as payroll (40,000 monthly and 48,000 weekly), superannuation (25,000 contributors), costing (labour and materials worth more than £6m a year) and stores accounting (£12m a year).

Eric is already calculating the monthly salaries and superannuation accounts of some 10,000 staff. Two inputs are employed at present: a tape input covers the permanent features of each individual's salary, and punched cards feed in the varying monthly increments.

Consideration is being given to the use of Eric for statistical analyses and operational research.

R.A.E.'s Corsair d.d.a.

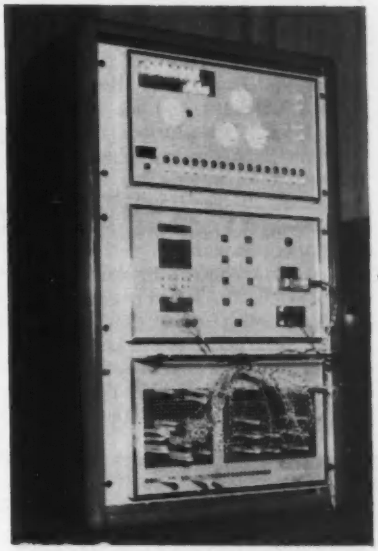
Experimental work by the Royal Aircraft Establishment, Farnborough, into the application of direct-coupling techniques to transistors, has resulted in their building Corsair, a fully transistorized transportable digital differential analyser. Computers of this type deal with information of a continuously variable nature as normally dealt with by analogue machines, but have the greater inherent accuracy and versatility of digital techniques.

The high-speed section of the machine employs surface barrier transistors, by Semiconductors Ltd., in directly-coupled circuits which do not

Right: Eric, an I.B.M. 650 data processing system for clerical work now installed in London's County Hall

Right: Corsair, an R.A.E.-built digital differential analyser, is fully-transistorized

Left: Analogue computers loaned to Loughborough College of Technology for recent course



require the usual coupling and limiting components, and operate from a single three-volt supply. Other sections employ Standard Telephones and Cables' TK 20 bi-directional transistors. Information is stored in a core matrix which is programmed on a simple patch panel. The bi-directional characteristics of the S.T.C. transistors allow them to perform both 'reading' and 'writing' functions.

Full use has been made of printed wiring and a packaged form of construction.

A.E.I. analogue for Ford

An Associated Electrical Industries' type 955 analogue computer is to be used by the (Birmingham) engineering research department of the Ford Motor Co. in the investigation of motor vehicle design. This investigation will include problems connected with suspensions, engine mechanisms and thermal dynamics.

The computer contains a total of 92 computing amplifiers. Sixty of these are for linear transfers while the remaining 32 are to be used in conjunction with simple non-linearities such as limit and dead space, and with six 20-segment function generators. Other non-linear units in the installation are six 5-gang servo-multipliers, and two high-speed Hall-effect multipliers.

Two 609's for U.K.

Two Panellit 609 information and computing systems have been completed for customers in the U.K. It will be recalled (these columns, October 1959) that the 609 system is built up from the Elliott 803 transistorized digital computer and data-handling equipment supplied by British Panellit, a member of the Elliott-Automation group with American associations. One of the systems is due to be installed in a Samuel Fox steel works. This will automatically decide the optimum positions for cutting steel billets to meet customers orders with the minimum of wastage.

The other installation, the destination of which is not yet disclosed, is for a high-speed temperature-scanning application. Operating from a tape programme, 450 thermocouple measurements will be scanned and logged every two minutes. The system will give warning if any measurement is outside permissible limits, or if the rate-of-change of temperature exceeds a predetermined figure.

An optimizing computer-controller

During a recent visit to Elliott's Elstree works, CONTROL saw 'Optimat,' an optimizing computer. This device will deal with the sort of plant situation where changes in uncontrolled variables, such as load, make it necessary to change the setting of individual control pointers in order to maintain optimum conditions. Optimat does this on a trial-and-error basis, making small changes in control-point settings and noting the effect—e.g. on output. If the effect is beneficial, a further similar change is made; if not, a different change is tried; and by successive steps optimum conditions are eventually reached.

The prototype CONTROL saw was designed to handle three variables and, even at this relatively low level of complexity, was understood to outperform the human operator. It can, however, make a mistake if the response of the plant is such that the quantity it is trying to maximize has more than one maximum, as the highest maximum will not necessarily be selected without some guidance from the operator. It is understood that Optimat is shortly to be applied experimentally to a full-size plant.

Analogue week at Loughborough

A course in basic analogue-computer techniques was held recently at Loughborough College of Technology. It was aimed mainly at those in industry or education who were contemplating the purchase of an analogue computer, or those whose computers are working on a schedule too tight to allow practice-time.

Of the fifteen people on the course, twelve were from industry and three from colleges. CONTROL was told that, provided the response is sufficient, a similar course might be held sometime next year.

Analogue computers were loaned to Loughborough by (left to right in the illustration) Louis Newmark (Model 3400), E.M.I. (Emiac), Elliott Brothers (Miniac), Saunders Roe (Miniputer), and Solartron (Minispace and Tutor).

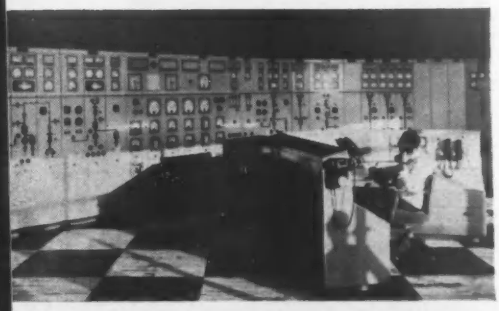
— ELECTRICITY —

Another C.E.G.B. station

CONTROL visited the latest C.E.G.B. station, Ferrybridge B in Yorkshire,

which has a total installed capacity of 300 MW provided by three 100 MW turbo-alternators. Two of these supply power via 13·8/132 kV transformers to standard lines, and the third via a 13·8/275 kV transformer to Monk Fryston Supergrid switching station some 2 miles away. This machine is connected to the 275 kV system and synchronized by remote control from the Supergrid station.

Automatic controls by Bailey Meters are provided for steam pressure, combustion, fuel pulverization and feed water. The main (electrical) control room and one of the three boiler control-rooms are shown in the illustrations. A feature of this station is that



Control rooms at the C.E.G.B.'s recently-opened Ferrybridge B power station. Top, the main electrical control room; bottom, one of the three boiler control rooms. Each of the three 100 MW sets is governed independently

the three sets are completely independent, each governed by its own control room.

. . . and at Willington A

Discussed in *Control in Action* in May 1959, the C.E.G.B.'s Willington A now has an instrumented water-treatment system designed to eliminate plant stoppages due to evaporator scaling or CO_2 corrosion.

Controls, by Honeywell to C.E.G.B.'s specification, co-ordinate flow control and pH value so that the pH value of water entering the evaporators is maintained at an optimum level. Water is initially softened by base-exchange, then dosed with a controlled flow of acid to decompose the bi-carbonate present. The acidified softened water is then fed to a degassing tower where free CO_2 is liberated. The degassed water, still containing a trace of CO_2 and a slight excess of acid, is then drawn off from the degassing tower sump and alkali-injected to a required pH before being pumped to storage tanks and thence fed to the evaporators.

An orifice plate and differential pressure-transmitter measure the flow of water through the entire plant. This flow is recorded and integrated, and automatically controlled by means of a diaphragm control valve. Liquid level in the degassing tower is also indicated and controlled pneumatically with a diaphragm control valve. pH is recorded and pneumatically controlled for both stages of the treatment process. The method of control is novel in that flow and pH control are co-ordinated by the use of averaging relays.

The rate of acid dosing is governed by the average of the signal from the liquid level controller (approximately proportional to flow) and the controlled air output from the pH controller. A second relay, manually adjustable, allows the acid dosage rate to be varied to accommodate changes in the total alkalinity of the untreated town's water. The acid dosing system can thus be reset to suit varying qualities of feedwater from different sources in the Derby area. The alkali dosing rate is governed by the average of the flow transmitter signal and the controlled air output of the second pH controller. The control system has been found to keep the pH value constant to within 0·2 pH.

—MACHINE TOOLS—

Ferranti-Bendix agreement

An agreement has been concluded between Ferranti and the Bendix Aviation Corp. for the sale in the U.S.A. of the Ferranti systems of machine tool control. These are the transistor-hydraulic continuous-path machine tool control equipment, numerical position control equipment and inspection machines.

Bendix—themselves machine tool control manufacturers—will market and service the British-built systems throughout the U.S.A., and set up a computer centre, initially in Detroit, to supply magnetic tapes for the equipment.

Bendix apparently consider the Ferranti systems to be particularly well suited to the U.S. market because of their flexibility and economy for small as well as large engineering plants. The main feature of the Ferranti systems is, of course, diffraction-grating measurement.

——STANDARDS——

U.K.-U.S. co-ordination

Britain and the United States have begun to co-ordinate their time and frequency transmissions. Participating in the project are the Royal Greenwich Observatory, the National Physical Laboratory, and the Post Office Engineering Department in this country, and, in the United States, the U.S. Naval Observatory, the Naval Research Laboratory, and the National Bureau of Standards.

The transmitting stations concerned are GBR (16 kc/s) and MSF (2·5, 5 and 10 Mc/s and 60 kc/s) at Rugby, England, NBA (18 kc/s) Canal Zone, WWV (2·5, 5, 10, 15, 20 and 25 Mc/s) Beltsville, Maryland, and WWVH (5, 10 and 15 Mc/s) Hawaii.

IN BRIEF

Transitron Electronic Ltd. has been set up at Bilton House, Uxbridge Road, Ealing, London, W.5, under D. P. O'Connell, to market the semiconductors of Transitron Electronic Corp., U.S.A. The main European subsidiary is at Zug, Switzerland.

Elcontrol's output increased by 30% during 1959, a factory extension has been completed at Hitchin, and a Special Products Division has been formed under G. S. Potter, to handle 'tailor-made' control schemes.

Guided missile range in the Outer Hebrides has control and instrumentation by Ultra Electronics. This equipment, pre-packaged for immediate use, has now been flown to Benbecula.

Vickers VC 10 jet aircraft are to have £700,000-worth of aircraft generation systems by Plessey, following a new licensing agreement between Plessey and Westinghouse Corp., U.S.A.

Two university scholarships are being sponsored by Ultra Electronics: one is a two-year research scholarship for an honours graduate in engineering; the other is an undergraduate sandwich course.

Sperry Gyroscope, U.S.A. (now a major division of Sperry-Rand) celebrated its 50th anniversary in April—British Sperry will follow suit in five years time.

Graphical techniques for control systems—6

N. G. MEADOWS
Wimbledon Technical College

The Bode diagram

This comprises two plots, one of gain in decibels against $\log \omega$, the other of phase against $\log \omega$, where ω is angular frequency. For an approximate Bode plot, straight-line-segment approximations are used for the gain curve, the procedure being illustrated by reference to a phase-advance network and a servo system.

Plot for phase-advance network

The transfer function for a simple phase-advance network is

$$\frac{e_o}{e_i} = A\frac{1+j\omega T}{1+jA\omega T} \qquad \ldots 1$$

where A is the d.c. attenuation. The gain in decibels is given by

$$G = 20 \log_{10} \left| \frac{e_o}{e_i} \right|$$

$$\text{where } \left| \frac{e_o}{e_i} \right| = \frac{[1+(A\omega T)^2]^{\frac{1}{2}}}{[1+(\omega T)^2]^{\frac{1}{2}}} \qquad \ldots 2$$

$$\therefore G = 20 \log_{10} A + 10 \log_{10}[1+(\omega T)^2] - 10 \log_{10}[1+(A\omega T)^2] \qquad \ldots 3$$

The first term on the right-hand side is constant in value, and is negative as $A < 1$. To plot the other terms the high- and low-frequency gain expressions are considered, and the gain plot for each term is approximated to by two straight-line segments.

Let $G_1 = 10 \log_{10}[1+(\omega T)^2]$. When $\omega T \leqslant 1$, $G_1 \simeq 10 \log_{10} 1 = 0$dB.

When $\omega T \geqslant 1$, $G_1 \simeq 20 \log_{10} \omega T$.

When $\omega = 1/T$, $G_1 = 0$. This value of ω is termed the 'breakpoint' or 'corner' frequency.

When $\omega = 10/T$, $G_1 = 20$dB; or, when $\omega = 2/T$, $G_1 = 6$dB.

Hence, this term rises at 20dB per decade, or 6dB per octave from the breakpoint frequency, and is zero below this frequency. Let $G_2 = -10 \log_{10}[1+(\omega AT)^2]$.

When $\omega T \leqslant 1$, $G_2 \simeq 0$. When $\omega T \geqslant 1$, $G_2 \simeq -20 \log_{10} \omega AT$. For $\omega = 1/AT$, $G_2 = 0$, and for $\omega = 10/AT$, $G_2 = -20$dB. Hence the gain curve for this term is zero up to the breakpoint frequency, $\omega = 1/AT$, and falls at 20dB per decade or 6dB per octave thereafter. Generalizing, a numerator term of the form $1 + j\omega a$ has a breakpoint frequency of $\omega = 1/a$ and the gain curve can be represented by a straight line on the zero dB axis to this frequency, followed by a line of slope +20dB per decade. A denominator term of this form will have an ensuing slope of −20dB per decade.

As the plot is logarithmic, the overall-gain curve is obtained by algebraically summing the separate gain-curves, as shown in Fig. 1 and exemplified by Eq. 3. The term $20 \log_{10} A$ is conveniently considered by shifting the origin upwards a corresponding amount, after summing the curves represented by G_1 and G_2.

Phase plot

For the numerator term of Eq. 1 the phase angle is $\phi_n = \tan^{-1}(\omega T)$ and for the denominator term $\phi_d = \tan^{-1}(A\omega T)$. As $\omega \to 0$, ϕ_n and $\phi_d \to 0$ and as $\omega \to \infty$, $\phi_n \to +90°$ and $\phi_d \to -90°$. At the breakpoint frequencies, $\phi_n = +45°$ and $\phi_d = -45°$. An approximate phase plot can be sketched from these values, as shown in Fig. 1, the resultant phase curve; i.e. $\phi_n - \phi_d$ being obtained by subtracting ordinates of the ϕ_d curve from those of the ϕ_n curve, at corresponding ω points. The maximum phase advance and frequency at which it occurs can be estimated as shown in Fig. 1. The graph shown is plotted for $A = 0{\cdot}1$ and $T = 2$ seconds. In practice a more accurate phase plot than is available from this approximate data may be necessary, and is easily obtained by reference to tangent tables. Note that the phase curves are not zero at the origin (0) since ω is not zero here.

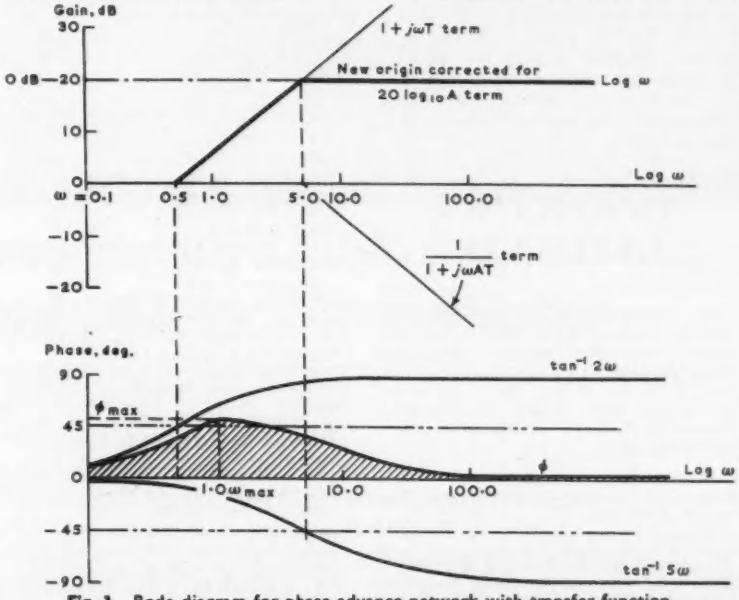


Fig. 1. Bode diagram for phase advance network with transfer function $e_o/e_i = 0{\cdot}1(1+j\omega/0{\cdot}5)/(1+j\omega/5)$

Plot for servo system

As a specific example a Bode plot is illustrated for a system with an open loop transfer function

$$\frac{\theta_o}{\theta} = \frac{2{\cdot}5}{j\omega[1+j\omega/2][1+j\omega/5]}$$

By inspection, the denominator terms have breakpoints at $\omega = 2$ and $\omega = 5$, while the numerator term is $20 \log_{10} 2{\cdot}5 \simeq 8$dB. The Bode diagram has the advantage of an expanded scale for the low-frequency data, and the lowest frequency of interest will be at the origin as the abscissa is $\log_{10}\omega$. In this example the lowest breakpoint frequency is $\omega = 2$, and conveniently the origin is assigned at $\omega = 0{\cdot}1$. This enables the term $1/j\omega$ to be plotted, the modulus being $1/\omega$ giving $-20 \log_{10}\omega$ in decibels. When $\omega = 0{\cdot}1$ this gives +20 dB and when $\omega = 1$, zero dB, with a resulting slope for this term of −20dB per decade. The total gain curve is shown in Fig. 2, with the re-

DATA SHEET—18

sultant phase curve ϕ. The term $1/j\omega$ contributes a constant lag of 90°, so that $\phi = -[90° + \tan^{-1}(\omega/2) + \tan^{-1}(\omega/5)]$.

Estimation of gain and phase margin

Gain margin : this is the amount by which the gain may change before the frequency-response locus touches the -1 point on the Nyquist locus, and is associated with a phase angle of 180° on the Bode plot, as shown at point *A*, Fig. 2. Drawing *AB* vertically to intersect the gain curve at *B*, and projecting *BB'* horizontally, gives the gain margin $0'B'$. As this is negative the system is stable.

Phase margin : this is the angle, measured from $-180°$ towards 0°, at which $|\theta_o/\theta| = 1$, i.e. $20\log_{10}|\theta_o/\theta| = 0$ and is hence associated with the point *D* at which the gain curve cuts the logω axis. Drawing *DE* vertically to cut the phase curve at *E* and projecting *EE'* horizontally gives the phase margin *A'E'*. In this example the phase margin is about 20°, a low figure which could be improved by reducing gain, assessed merely by displacing the logω axis, upwards for a decrease and down for an increase. If gain reduction is not tolerable, phase-compensation may be necessary.

Errors : at the breakpoint frequency a term of the type $(1 + j\omega T)$ or $(1 + j\omega T)^{-1}$ gives an actual gain of $\pm$3dB and this is the maximum error in the gain plot for such a term. Location of the 3dB point at the breakpoint frequency enables a more accurate gain plot to be drawn if desired, the curve ultimately running asymptotically to each of the straight line segments.

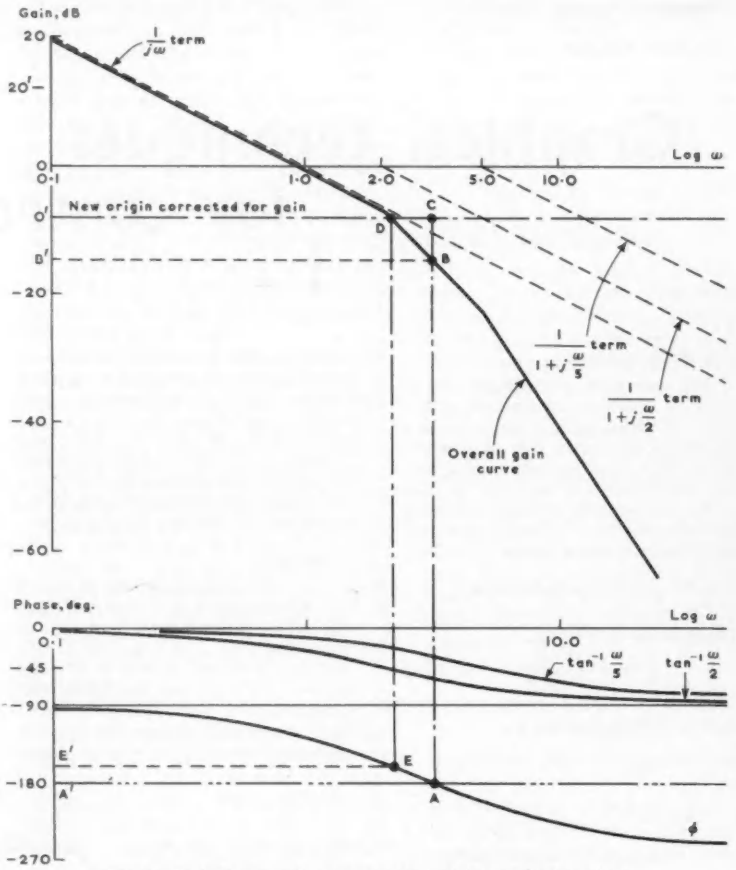


Fig. 2. Bode diagram for servo-system with transfer function $\theta_o/\theta = 2{\cdot}5/(j\omega[1+j\omega/2][1+j\omega/5])$

LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.S. British Computer Society, Brit. I.R.E. British Institution of Radio Engineers, I.E.E. Institution of Electrical Engineers, R.Ae.S. Royal Aeronautical Society, S.I.T. Society of Instrument Technology. I.Mech.E. Institution of Mechanical Engineers.

TUESDAY 3—FRIDAY 13 MAY
Mechanical Handling Exhibition and Convention, Earls Court.

WEDNESDAY 11 MAY
Radio Guidance in the Automatic Landing of Aircraft by J. Shayler. 6.30 p.m. Brit.I.R.E.
Sixth Conference of Standards Engineers. Connaught Rooms. Organized by British Standards Institution jointly with Institution of Production Engineers. Tickets: Secretariat, I.P.E./B.S.I. Committee, British Standards House, 2 Park Street, London, W.1.
Data Processing Section Annual General Meeting. 6.15 p.m. S.I.T.
A Recording Stereocomparator by A. E. Adams. 7 p.m. S.I.T.

WEDNESDAY 18 MAY
Symposium on Electronic Equipment Reliability. Sessions at 10.30 a.m., 2.30 p.m. and 5.00 p.m. I.E.E.

FRIDAY 20 MAY
Servomechanisms and Electronic Engineers—the Present and the Future by M. James. 7.00 p.m. Brit.I.R.E.

MONDAY 23—SATURDAY 28 MAY
Instruments, Electronics and Automation Exhibition, Olympia.

TUESDAY 24 MAY
S.I.T. Annual General Meeting. 6 p.m. Presidental Address. 7 p.m. R. S. Medlock.

WEDNESDAY 25 MAY
Discussion on *New Semiconductor Devices and their possible Applications*. Opened by A. F. Gibson and G. King. 5.30 p.m. I.E.E.

WEDNESDAY 1—FRIDAY 3 JUNE
Instrument Society of America's 6th National Symposium on *Instrumental Methods of Analysis*, Montreal. Information: Director of Technical & Educational Services, I.S.A. 313 Sixth Ave., Pittsburgh, Penn., U.S.A.

WEDNESDAY 8—FRIDAY 10 JUNE
3rd Symposium on *Gas Chromatography*, Edinburgh. Details: L. Brealey, Boots Pure Drug Co., Nottingham.

FRIDAY 10—SUNDAY 26 JUNE
British Exhibition, Coliseum, New York.

WEDNESDAY 15—WEDNESDAY 29 JUNE
7th International Nuclear Congress and Exhibition on Electronics, Rome. Details: Secretariat 14 Via della Scrofa.

SATURDAY 18—WEDNESDAY 29 JUNE
S.I.M.A. Exhibition of British Scientific Instruments, Moscow.

FRIDAY 24 JUNE—FRIDAY 8 JULY
International Machine Tool Exhibition, London.

MONDAY 27 JUNE—WEDNESDAY 6 JULY
Moscow Congress for Automatic Contr'. Applications: Hon. Sec. Group A, B.C.A.C., c/o I.Mech.E.

MONDAY 4—THURSDAY 7 JULY
2nd Conference of the B.C.S., Leeds. Details: Miss D. E. Pilling, The University, Leeds.

THURSDAY 21—WEDNESDAY 27 JULY
Third International Conference on Medical Electronics, Olympia.

LOOKING FURTHER AHEAD

MONDAY 15—SATURDAY 20 AUGUST
11th Congress of the International Astronautical Federation, Stockholm.

WEDNESDAY 31 AUGUST—WEDNESDAY 7 SEPTEMBER
Annual meeting of the British Association for the Advancement of Science, Cardiff, S. Wales.

THURSDAY 1 SEPTEMBER
Joint Symposium on *Rocket and Satellite Instrumentation*. B.I.S. and S.I.T.

MONDAY 5—SUNDAY 11 SEPTEMBER
S.B.A.C. Flying Display and Exhibition, Farnborough.

TUESDAY 13—THURSDAY 15 SEPTEMBER
5th International Instruments and Measurements Conference and Exhibition, Stockholm. Details: AB Anders Beckman, Smalandsgatan 2, Stockholm.

WEDNESDAY 21 SEPTEMBER—SATURDAY 1 OCTOBER
International Factory Equipment Exhibition, Belle Vue, Manchester.

WEDNESDAY 19—WEDNESDAY 36 OCTOBER
Interkama International Congress and Exhibition for Instrumentation and Automation, Düsseldorf.

SUNDAY 12—FRIDAY 17 JUNE 1961
Conference on *Components and Materials used in Electronic Engineering*. Central Hall, Westminster.

WEDNESDAY 4—THURSDAY 12 OCTOBER 1961
Second Electronic Computer Exhibition and Symposium. Details: D. C. Scoones, Peate, Marwick & Mitchell & Co., 94-98 Petty France, S.W.1.

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SC26

Last month's I.E.E. Symposium on Data Handling and Display Systems for Air Traffic Control threw up the old problem of man versus the machine . . .

An Unsolved Problem

A SURPRISINGLY WELL-ATTENDED SYMPOSIUM on air traffic control was held at the Institution of Electrical Engineers on April 8. Organized by the I.E.E.'s Electronics and Communications Section, the Symposium was of obvious appeal to the air traffic controller and those interested in data handling and computation, as well as to the hard core of communications and navigational experts.

The Symposium was in afternoon and evening sessions, the former being concerned with flight information processing, and the latter with radar data handling.

Flight information processing

The first paper was *A survey of data handling for air traffic control* by J. C. Farmer—who presented the paper—and M. F. Whitney of the Ministry of Aviation. This brought home the size of the problem and suggested that the ultimate was the elimination of all manual processing, the display of only that information which is relevant to the job in hand, and the automatic computation of sums, conflict detection and possible solutions. The equipment exists to build a.t.c. systems for the next two decades but a more difficult task is to determine the optimum relationship between man and machine. Reliability is paramount.

Ir. C. G. H. Scholten's (N.V. Hollandse Signaalapparaten) paper *An electronic computing system for air traffic control* described the Satco (Signaal air traffic control) system. A dead-reckoning Satco with teleprinter input and output has been built for Amsterdam, and simple conflict search and automatic display are now under development for that airport. More sophisticated equipment—automatic conflict resolution, automatic input from and control of radars etc. —is still in the 'thinking and dreaming' stage.

An experimental electronic data-processing system for air traffic control under development for the Minstry of Aviation and to be installed at the Oceanic Area Traffic Control Centre, Prestwick, was briefly described by J. S. MacMullan, H. S. Bray and J. A. Llewellyn. The present state of development is such that a full description would be premature, but the idea is to investigate methods of using automatic equipment to relieve controllers of certain routine data-processing work, and also to investigate existing control procedures with the aid of automatic equipment. The computer will be a Ferranti Apollo—a new high-speed transistorized parallel computer. An experimental control arrangement comprising data-processing equipment, four communicators and four controllers will be operated in parallel with the existing operational system as an open-loop system, in early 1961. Later, closed-loop control will be carried out under simulated conditions.

The discussion following this Session was opened by W. H. Garnett who stressed the importance of reliability and remarked that it appeared to be an example of man versus the machine. He asked if the machine rather than the man should make decisions. D. L. T. Thomas of Standard Telecommunications Laboratories continued in the same vein. He pointed out that there will be no 'holding' of future supersonic aircraft and that, as the controller and the controlled aircraft form part of a servo loop, the one feature that will decide whether man or machine should take decisions is their relative response times.

J. D. Bailey of A.E.I. wondered whether data processing was the answer to the problem after all. The systems envisaged seemed to consist of data handling, data processing, controller processing, transmission to the aircraft, pilot processing and so on. Perhaps it was more of a process control problem than a data processing one. He also saw the system as a servo loop with data processing indicating a very small step to the controller.

Some light relief was injected into the proceedings by J. H. H. Merriman of H.M. Treasury. He had been looking up computer reliability and had been impressed by a figure of over 200,000 hours. However, according to Murphy's third law, which was new to most of his audience, 'the greater the odds are against an event occurring, the shorter are the odds against it occurring the first time you try it.'

Farmer responded as best he could in the short time available to the many very general suggestions from the floor. He again stressed the importance of reliability and said it was necessary for us to have more faith in the machine. However, each aircraft is full of passengers and there are large numbers of aircraft. In general he agreed with Bailey but . . . !

Radar data handling

The second Session opened with *An experimental system for automatic radar target detection and digital coded plot extraction and transmission* by G. L. F. Hinkley of R.A.E. This is an experimental system for treating data collectively from a number of differently-sited radars. It converts the radar data from polar to Cartesian co-ordinates and transmits the encoded Cartesian data over long distances using a single telephone circuit.

Semi-automatic flight control using extracted radar data, by C. C. Fielding and J. G. Gibbs of R.R.E. was delivered by the former. They suggested that modern radars, digital data handling and digital ground-air data links could provide a major step forward in flight control. It is essential, however, to maintain a proper balance between man and machine. The latter could perform routine assessments, repetitive tasks and computation. Man is flexible and could inject information into the machine, monitor and make decisions. The machine should aid the controller and increase his efficiency.

Methods of extracting radar data for automatic processing, a paper by N. J. Smith and B. W. Oakley of R.R.E., and given by Smith, was an excellent review of the man-versus-machine problem. Computers do not make mistakes, but the human operator is adaptable and can exercise choice. Computers should not make decisions, for they do fail. Furthermore, the human operator employs 'pattern recognition' and a sufficiently complex computer is a long way off as yet. The computer is not yet a tool for a really complex situation, although satisfactory for part of a situation. The machine might, however, be satisfactory over seas and undeveloped countries.

What does an operator do ?

The discussion was extremely lively. E. V. D. Glazier (R.R.E.) objected to a reference by Fielding to three-dimensional radars, remarking that pilots didn't like height radars and preferred aneroid instruments for 500-ft vertical separation.

D. D. Lipman of the Air Traffic Control Experimental Unit at London Airport made a slashing if jocular attack on the thinking apparent at the Symposium. He felt that closed-loop control was quite out of the question on grounds of reliability. Civil aircraft are not guided weapons 'which have been known to abort.' He called for automatic assistance rather than automation, 'building from what we know to what we think we ought to want.' He felt that machines could not compete with human judgment. E. Eastwood of Marconi's took the opposing view, saying that electronics may be more reliable than man. Furthermore, what function does the operator really fulfil? We need to know what he does, then simulate it. 'Operators are not truly reliable.'

W. Ross of R.A.E. said that an operator can 'recognize' a target and see trends, and R. E. Young of Armstrong Whitworth that an operator can see signals in noise and anticipate trends. However, pilots fly under instrumental control and, if automatic landing and take-off were possible, why not automatic control? 'You cannot believe all you read in the newspapers about guided weapons.'

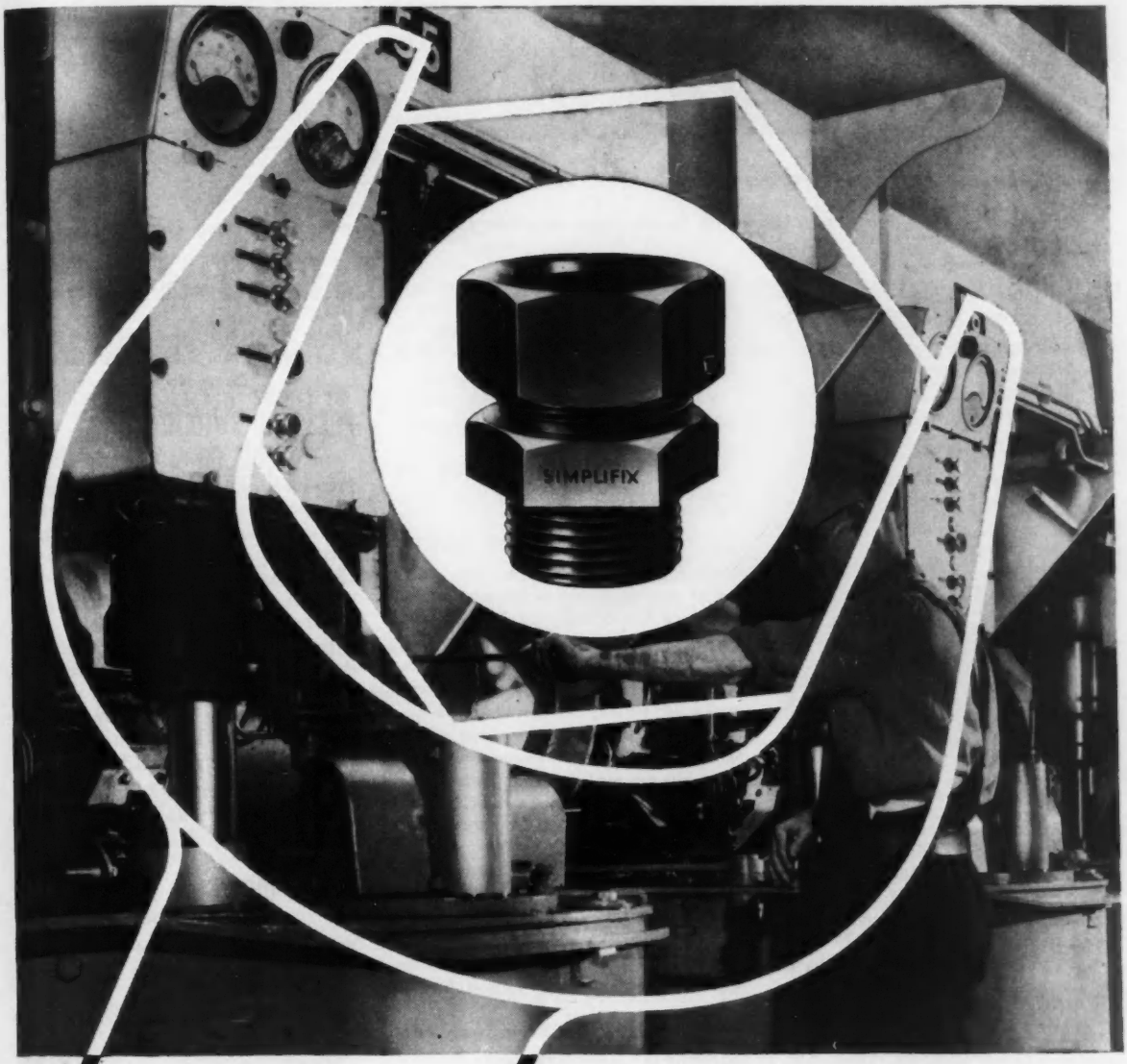
W. Bond of the Ministry of Aviation also disagreed with Lipman, asking 'is not a.t.c. overloaded?'

R. Benjamin of the Admiralty Surface Weapons Establishment said that man can handle an extremely wide range extremely badly, and that the machine was only restricted in its ability to recognize patterns. We should balance man, who receives all but uses little, against the computer which can use all but may (rarely) miss all.

Replying, Hinckley said the job is there and has got to be done. He did not agree that the case for the human operator was so strong and felt that a machine should do at least as well. Gibbs replied in similar vein remarking that automatic control gives time for planning.

N. J. Smith said they could not compare what a computer will do with what a man could do—the computer's mistakes are found out. Man can do more than most computers, but how often do we get really valuable information that a computer cannot give? He saw little future in man-monitored automatic systems, saying that the operator must be either kept or dispensed with.

A supplement to Part B of the Proceedings of The Institution containing the complete proceedings of the Symposium will be published in due course.



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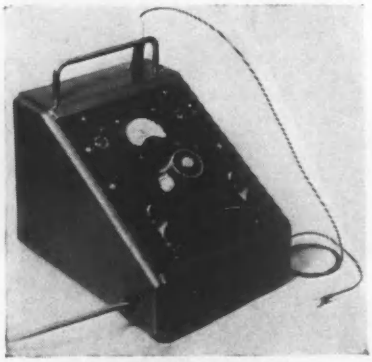
FIELD PLOTTER

replaces electrolytic tank

This resistance analogue is effectively a two-dimensional version of the electrolytic tank. The electrolyte of the tank is replaced by a special resistance paper, on



Special skill not required

which silver electrodes are painted. Maps of potential and flow lines are easily drawn using the F.P.92 field plotter.

The price of this unit, made by Servomex Controls, is very much less than that of a standard tank.

Circle **No 520** on reply card

TRIP AND WARNING AMPLIFIER

for d.c. inputs

Operating on a standard 230 V a.c. supply, this d.c. amplifier is designed for use with d.c. outputs such as those from thermocouples. Six standard current and voltage inputs are catered for, varying from 0–10 μA to 0–30 mA and 0–10 mV to 0–150 mV. Ranges are changed by means of plug-in cards.

'Warning' and 'trip' lights are provided, as well as control contacts which will handle 2 A at 230 V a.c. The action is reversible, switching in or out at two pre-set levels where required.

Made by Elliott-Automation, it is claimed that the unit may be set to an accuracy of 0·1% of trip-level.

Circle **No 521** on reply card

THICKNESS GAUGE

for non-conductive coatings

Designed to measure the thickness of non-conductive coatings on non-ferrous metals, this instrument has three ranges covering 0–0·0025, 0–0·005, and 0–0·01 in. Thickness is read directly from a calibrated meter, to an accuracy of ±10% of the actual reading. This is maintained down to one-tenth f.s.d.

The 'Accuratest' gauge operates by change in the inductance of the probe caused by proximity of the basis-metal.

Made by Nash and Thompson from a design by Caloral Products, the gauge is mains operated.

Circle **No 522** on reply card

OSCILLOSCOPE

direct digital reading

Claimed to incorporate the first direct digital reading system in an oscilloscope, the Type 425 is designed for use with frequencies from d.c. to 60 Mc/s. The tubes operates with 12-kV acceleration-potential to give high sensitivity and resolution; display area is 10 × 5 cm.

When the instrument has been set up by an engineer, amplitude and time measurements are read as actual digits on the tube-face. It may also be directly connected to punched-card equipment for recording and analysis.

Modular construction is used and a variety of plug-in units are available which enable the range and performance to be varied and extended. Manufactured by Du Mont Laboratories (USA), distribution in England is by Leland Instruments.

Circle **No 523** on reply card

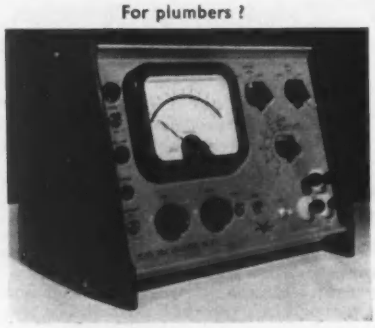
UNIVERSAL MULTIMETER

with voltage memory

Full-scale readings of voltage from 0·5 to 2000 V, and current from 0·5 μA to 2 mA, are available on this instrument. Input impedance is 10^5 MΩ on voltage ranges, and is claimed to be zero on current ranges.

A novel feature is a 'memory' which enables voltage measurements to be stored for several hours and erased at will. Resistance may be measured up to 1000 MΩ.

For plumbers ?



The multimeter, known as the E.R.I.C., is available from Southern Instruments.

Circle **No 524** on reply card

PRESSURE SWITCHES

will take 50% overload

Pressure-sensitive capsules operate microswitches rated at 5 A, 250 V a.c. These are either single-pole (type GS300), in four pressure ranges from 0·45–1·6 lb/in² to 1·95–21·6 lb/in², or double pole. The latter operate in pressure ranges from 0·13–1·6 lb/in² to 0·4–21·6 lb/in².

These units are mounted in aluminium-alloy cases, with gasket-sealed covers to provide protection against the weather. Pressure setting is adjusted by a screwdriver, and is self-locking.

Manufactured by Firth Cleveland, who claim that the capsules will withstand overloads of up to 50% above declared range.

Circle **No 525** on reply card

TIMING UNIT

and pulse-counter

This instrument may be set to time periods up to 100 minutes in tenths of

Crystal clear

a second. It may also be used to measure time intervals within this range.

Pulses are generated by a crystal-controlled oscillator, the accuracy of which is claimed to be 0·025%. The display tubes are arranged to show tenths of seconds and seconds up to one minute, then minutes in decades up to a hundred minutes.

Manufactured by Sargrove Electronics.

Circle **No 526** on reply card

FREQUENCY METER

10 c/s to 1000 Mc/s

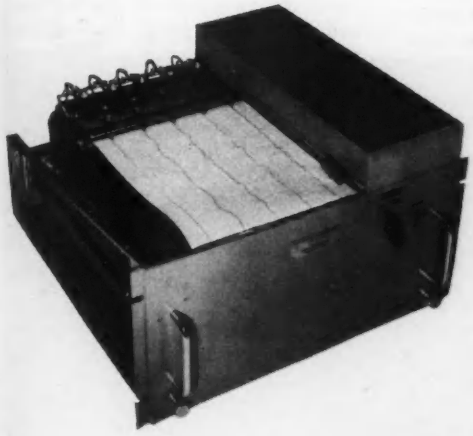
This unit is a heterodyne frequency-meter, and consists of a crystal-con-

CAPTURE

TRANSIENT PHENOMENA FOR GOOD WITH

High-speed PEN RECORDERS

Continuous recording of rapid, transient or oscillatory phenomena is made possible with Kelvin Hughes High Speed pen recording instruments. A wide range of instruments is available including new units which will permanently record up to 8 variables simultaneously. When used in conjunction with special Kelvin Hughes bridge amplifiers and power units, the recorders will measure strain, force, displacement, drag, pressure, acceleration and similar variables, providing instantaneous permanent recordings. Rapid response, versatility and dependability make them well suited for research work in aerodynamics, rockets, hydraulics, computers, and countless applications in industry, including civil engineering, mining, production testing of motor cars and tractors.



Ruggedly built and insensitive to external vibrations, Kelvin Hughes pen recorders will operate effectively under the most exacting conditions in vehicles, aircraft, and where heavy industrial plant is operating.

Please write for technical literature. Kelvin Hughes specialists are freely available to advise on any particular application for single- or multi-channel recorders in industry.

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trolled frequency-standard controlling a signal generator, a mixing circuit, and a frequency indicator.

A frequency of 1 Mc/s is derived from either an internal or external frequency standard, and reduced by division to 100 kc/s. It is then distorted to produce a spectrum of harmonics 100 kc/s apart. A free running interpolation oscillator covering 0–100 kc/s is then added to the selected frequencies obtained from the harmonic spectrum, and the unwanted frequencies generated by this mixing process are filtered out.

Manufactured by Rohde and Schwarz, distribution is by Aveley Electric.

Circle **No 527** on reply card

POWER SUPPLY
for transistor-circuit testing

Primarily for laboratory use, a transistor power-supply provides a stepless output from 0 to 15 V d.c. at a maximum current of 500 mA. Full current is available over the entire voltage range.

Stabilization is maintained for mains fluctuations of + 5% to − 10%, input voltages being 200–250 V a.c. in 10 V steps. Source impedance (at d.c.) is less than 0·01 Ω, giving a regulation of better than 5 mV. Ripple is stated as less than 1 mV peak-to-peak.

Low source-impedance

Made by Advance Components, the PP5 incorporates a grade-1 meter which may be switched to monitor either voltage or current output.

Circle **No 528** on reply card

FREQUENCY STANDARD
of high accuracy

A 5-Mc/s frequency source incorporates a high-performance quartz crystal, in a constant-temperature oven, and a four-valve maintaining circuit.

The signal is claimed to be stable to within ±4 parts in 10^9, ageing at a rate of less than 1 part in 10^9 per day.

Power supplies required for this S.T.C. instrument are 6·3 and 12·6 V a.c., and 120 V d.c. Overall size of the 90 LQE 801 is $6\frac{1}{2} \times 3 \times 4\frac{7}{8}$ in.

If more elaborate temperature control of the crystal is allowable by using an additional unit, the signal can be produced with stabilities within ±4 parts in 10^{10}. This unit, designated type 90LQU802, measures $10 \times 8\frac{1}{4} \times 7\frac{1}{8}$ in.

Circle **No 529** on reply card

RECORDER AND HOUR METER
with clockwork drive

This unit enables the running time of equipment to be recorded graphically, and since the recorder is clockwork-driven shows shut-down periods which are due to supply failure. The stylus is solenoid-operated, and requires 200 V d.c. at a current of 5 mA. The chart is driven by a 15-day movement normally at 1 in./h. Accuracy is ± 5 min. over this period.

Made by A.E.I., this self-contained unit measures $5\frac{1}{2} \times 4\frac{1}{2} \times 4$ in.

Circle **No 530** on reply card

LEVEL INDICATOR
capacitance-operated

A continuous level-indicator uses a capacitance probe in conjunction with an electronic control unit, which indicates incremental change of capacitance in the electrode unit as the contents level varies. The electrode system may be rigid, or flexible when container depth is in excess of 6 ft. Electrodes are available up to 60 ft in length.

The Levelog indicator is housed in a dustproof and waterproof case, which is provided with three ¾ in. conduit entries. Made by Thomas Industrial Automation, it may be calibrated in any appropriate units.

Circle **No 531** on reply card

AUDIO-POWER METER
range 0·1 mW to 10 W

Designed to measure audio power, this unit also directly determines source-impedance of equipment operating in the range 10 c/s to 50 kc/s.

The instrument measures output power by providing a resistive load of high-power wire-wound resistors. Forty values of resistance are distributed logarithmically over 2·5 Ω to 20 kΩ, and are selected by rotary switches. Voltage across the selected load is fed to a transistor amplifier which actuates the meter. A variable attenuator is automatically switched with the resistances so that a direct reading is obtained for all values of load-resistance.

Accuracy is ± 0·5 dB on the ×1, ×10, and ×100 impedance ranges, and ± 1 dB on the ×1000 range. Source impedance is measured by setting the load for maximum output. Model 610C, made by Dawe Instruments, is powered by self-contained batteries.

Circle **No 532** on reply card

AUTOMATIC SCALER
with high-voltage supply

A combined scaler and timer incorporates a stabilized high-voltage supply, a high-gain input amplifier and a pulse height analyser. A ratemeter facility is provided with push-button selection of 1000, 10,000 and 100,000 counts per second.

Easy to read

The scaler may be stopped automatically at pre-determined counts up to 10^5, and at pre-determined times up to 10^3 seconds. The timer can alternatively be used as a second scaler with its own pulse-height discriminator, the timing system being referenced to the mains frequency; provision is also made for using an external frequency standard. Input sensitivity is 5 mV negative-going and 5 V positive-going. The amplifier gain is switch-selected in six stages from 25 to 1000, and there is a stabilized high-voltage supply of 250–2000 volts in two ranges.

The Type N610 is supplied by Ekco Electronics in a case $19 \times 17\frac{1}{2} \times 15$ in.

Circle **No 533** on reply card

MULTI-POINT SCANNER
for temperature indication

Designed for continuous monitoring of temperature, this instrument measures the outputs from up to twelve thermocouples or resistance bulbs. The scanning is accomplished by a rotary mercury-switch, driven by a synchronous motor, the twelve inputs being scanned over a 3-minute period. A manual selector-switch enables the cycling to be halted, and any individual temperature to be observed at leisure.

The instruments can be arranged for two types of action. A single, maximum temperature can be pre-set on the scale

SEE

THE BURROUGHS **E.101 MKIII** COMPUTER

FOR:

Electronic speed

Proven reliability

Maximum versatility

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1. DIRECT KEYBOARD INPUT—
Data is entered directly into the computer, and may be printed on entry. No special preparation is necessary. This is an E.101 exclusive.

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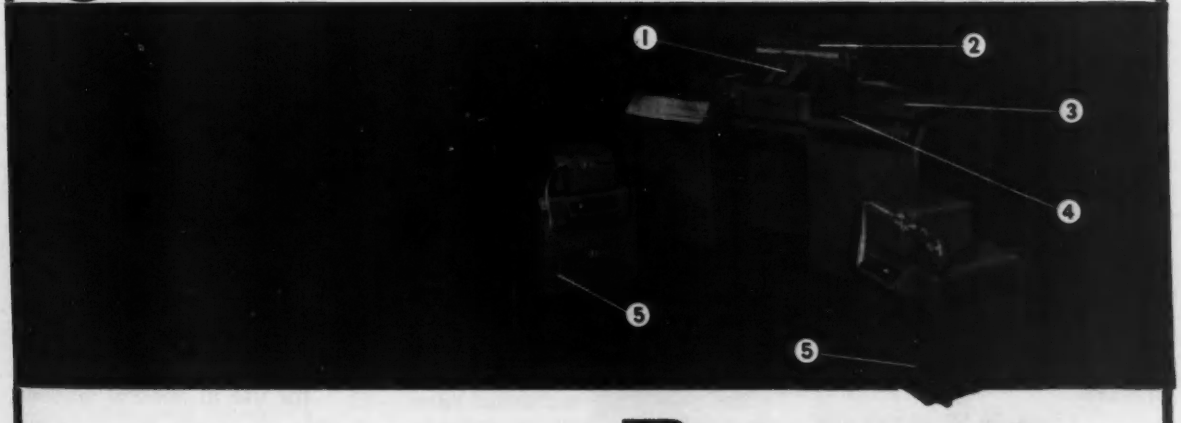
A highly flexible printer, incorporating an interchangeable 4-position printing and control unit, provides fast, direct printed output of intermediate and final results without using punched tape or punched cards. Another E.101 exclusive.

3. ACCESSIBLE PINBOARD PROGRAMMING—
The E.101 has a powerful and comprehensive command structure. Programs are easy to write, easy to set up, easy to record, easy to change. Every step is fully visible, and individually accessible. Auto-codes, complex plugboards, punching operations are eliminated.

4. COMPREHENSIVE OPERATOR CONTROLS—
Nine selective start-up points for automatic operation, and manual switches for the inclusion of special instructions, are designed to permit the exercise of maximum personal judgment at all stages of the operation.

5. OPTIONAL INPUT/OUTPUT ADJUNCTS—
Three paper tape or punched-card channels are available for entry of additional data, and unlimited extension of program capacity. A paper tape output unit is available to provide external memory, or link-up with other equipment.



NEW DIMENSIONS IN DATA PROCESSING BY **Burroughs**

SEE US AT THE BUSINESS EFFICIENCY EXHIBITION—BIRMINGHAM—STAND No. 90

Burroughs Adding Machine Ltd., Avon House, 356-366 Oxford Street, London, W.1. Telephone: Hyde Park 9861

Scans twelve inputs

and, if the temperature at any of the scanned points reaches this, scanning stops and an alarm or trip action to shut down the machinery comes into operation. In the second arrangement, two temperatures can be set on the scale. If any of the temperatures scanned reach the lower point, a relay is operated and this provides the necessary contact for an alarm; then, if the temperature reaches the second, a trip action is brought into operation.

Manufactured by West Instrument, this instrument has a keyed setting knob, so that when the key is withdrawn the pre-set levels cannot be changed.

Circle **No 534** on reply card

UNIVERSAL pH METER
and d.c. potentiometer

An improved version of an original model, the M4989 has been designed to meet B.S.S. 1647 accuracy.

It consists of an electrometer-valve potentiometer calibrated in pH units and millivolts, reading respectively to 0·0001 pH unit and 0·1 mV. The value of measured e.m.f. or pH is read in a straight line through three windows in the panel.

The null detector is a self-contained reflecting galvanometer, and forms part of a compact removable unit with its own 2-V light source, reflecting mirrors and scale.

The valve filament current (45 mA) and supply for the light-source are supplied from two 2-V external accumulators, and an internal 15-V battery provides anode and potentiometer current of 500 μA. Made by Doran, the complete unit weighs 22 lb and measures 12¼ × 12¼ × 10 in.

Circle **No 535** on reply card

D.C. AMPLIFIER
for moving-coil galvanometers

Designed for the operation of high-frequency moving-coil recording galvanometers from a high-impedance source, these amplifiers may be accommodated within a standard 19-in. panel assembly.

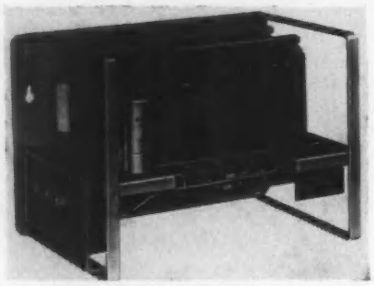
Sensitivity is variable from 250 mA/V to 2·5 mA/V, by the controls on the front panel. Push-pull stages are used throughout to assist in cancelling drift, and the unit is completely isolated from earth. Made by Hatfield Instruments, the LE 490 operates from 200 to 250-V 50-c/s mains. It is claimed that changes up to ± 10% in mains voltage produce negligible drift.

Circle **No 536** on reply card

PULSE SOURCE
crystal controlled

An electronic precision pulse-source is claimed to have a time-interval error of only a few seconds per annum. A crystal-controlled oscillator generates a basic frequency which is fed to a series of binary dividers, from which (in the standard chronometer) are produced square-wave pulses at intervals of 1, 30 and 60 seconds; other outputs are available on request.

Frequency stability is achieved by operating the crystal over a particular part of its characteristic, but where excessive ambient variations are encountered thermal compensation can be provided.



Inside story

The A.T.E. crystal chronometer is available from Communication Systems; power supply required is 24 V d.c.

Circle **No 537** on reply card

DIFFERENTIAL COUNTER
accepts two pulse-trains

Operating at 28 V d.c., this counter accepts two trains of pulses, one adding and the other subtracting, and indicates the resultant. It was developed initially for aircraft re-fuelling, where one flow-meter measures fuel-flow to the engines and another fuel-flow into the tank.

Two push buttons are located below the figures which enable the counter to be reset to zero or set to a predetermined figure. These buttons are two-stage switches and control fast and slow adding and subtracting pulses. The method of reset is to push either the adding or subtracting buttons fully home when fast pulses will be fed to the counter. When the approximate reading is reached the button is released and if pushed half way single pulses can be fed to the counter. Reset pulses are obtained from a circuit which is built into the counter.

The type 1400 is manufactured by Counting Instruments.

Circle **No 538** on reply card

ULTRASONIC FLAW-DETECTOR
with c.r.t. display

An ultrasonic flaw-detector, the Mark 2, has an operational frequency range of 0·5 to 10 mc/s, and a maximum depth range of 20 ft in steel.

The display is on a 5 in. diameter c.r.t., the time base of which has speed continuously variable from 1 in. to 20 ft echo distance. A trace-delay control enables the operator to expand any section of the display. Available from Ultrasonoscope, this unit operates from any standard 50-c/s supply, power consumption being 120 W.

Circle **No 539** on reply card

VIBRATION LIMIT CONTROLLER
with moving-coil pick-up

This unit is designed to measure, monitor, and record vibration in machines and structures. It operates by continuously comparing the output from a moving-coil pick-up with a fixed bias-voltage. A trip-valve, with a heavy-duty relay in its anode circuit, is triggered if the pick-up signal exceeds a pre-set level, and the relay either shuts down the machine under examination or rings an alarm.

The pick-up gives a voltage output directly proportional to vibration frequency over the range 20–400 c/s. A signal representing displacement is obtained by applying the output voltage to an integrating network, followed by rectification and amplification circuits. The resultant d.c. output drives a meter calibrated in peak values of displacement.

The type 1434 has a sensitivity control giving four ranges: 0–0·001, 0–0·003, 0–0·010, and 0–0·030 in. It may be set to trip at any vibration level between 20% and 100% of meter f.s.d. on any range.

Made by Dawe Instruments, the controller consumes 40 W from 110 or 200–250 V a.c. mains.

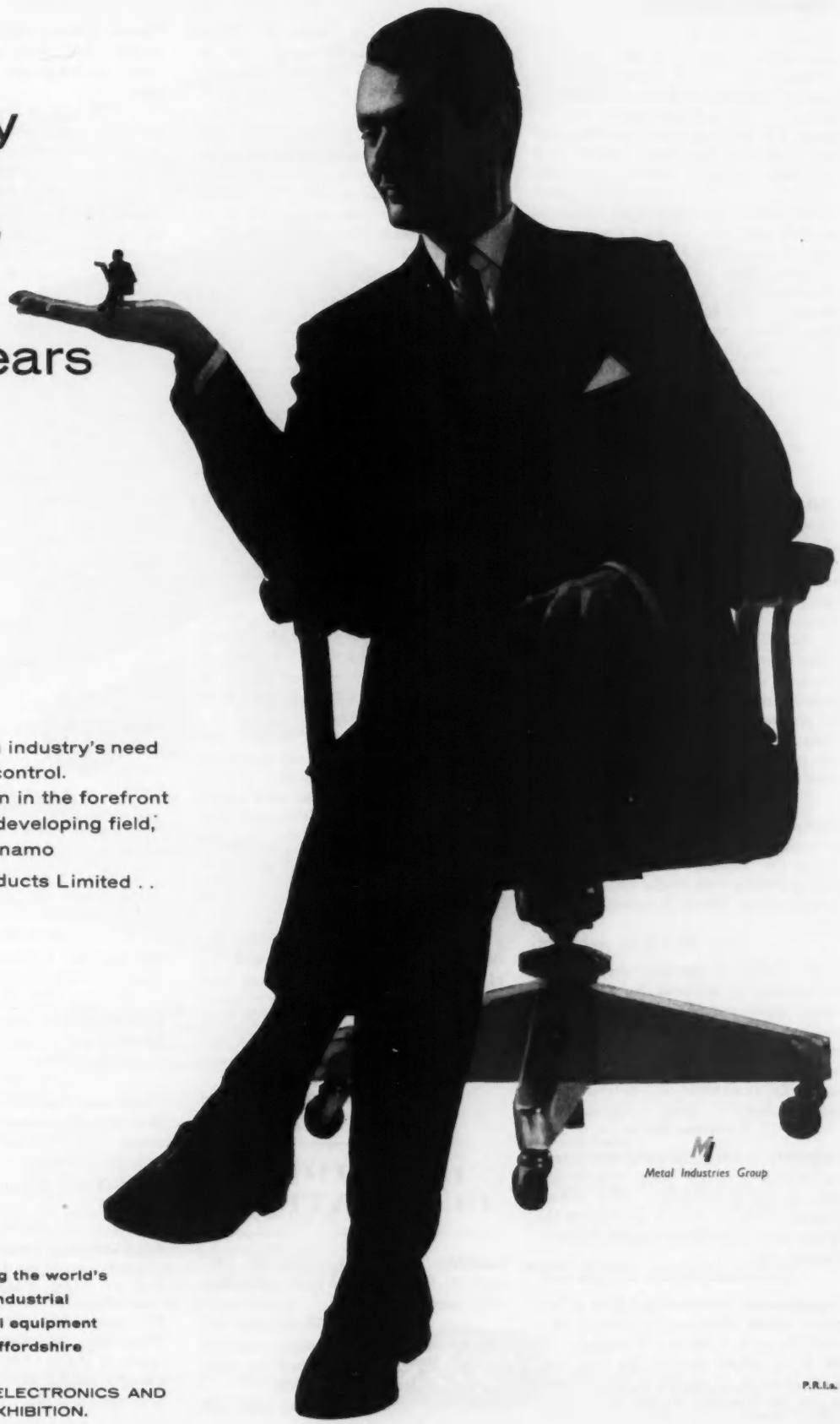
Circle **No 540** on reply card

MAGNETIC LOGICAL ELEMENTS
for use in control systems

A range of magnetic logical elements have been designed to work together and to be incorporated into control schemes.

They are made in the form of mechanically-coded standard packages. The element is a plug-in unit consisting of a nylon frame moulded to form a handle

twenty times larger in ten years



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at one end and having a 32-way plug and socket connexion at the other.

Two printed-circuit component boards, one for input-circuit components and the other for the magnetic-circuit components, are fixed into this frame and connected to the plug. Each assembly is a complete logical element providing 'and', 'or', 'not', 'memory' and 'time delay'. As much logic circuit as possible has been provided for on each logic element.

All packages have the same physical dimensions and in each moulded handle there is a label denoting the logical function. These units, manufactured by English Electric, are designed to slide into a steel receptacle which will hold a number of the elements side by side.

Circle **No 541** on reply card

QUICK LOOKS

Hydraulic accumulators. Three series of these devices have been added to an existing range. All three are of screwed-end construction, and they incorporate safety interlocks to prevent the unit being dismantled whilst under internal pressure. Series II is for pressures up to 2000 lb/in² with capacities ranging from 8 to 20 gallons. Series III is for pressures up to 5000 lb/in² with capacities ranging from 1 to 8 gallons. Series IV is for pressures up to 5000 lb/in² with capacities ranging from 8 to 20 gallons. Various port sizes and flanges are available; made by Industrial Hydraulics.

Circle **No 542** on reply card

Digital-display cathode-ray tubes are now in experimental production by the M.O. Valve Co. Display is bright, may be viewed from a wide angle, and is almost instantaneous. Screen diameter is about 1¼ in.

Circle **No 543** on reply card

Artificial-lighting control by the intensity of daylight is achieved by a printed-circuit photo-electric relay. Lighting is automatically switched on or off at pre-set daylight levels. Made by Londex the unit operates from 200 to 250-V a.c. mains, and is mounted in a weather-proof cast-iron case.

Circle **No 544** on reply card

Electronic continuous weighers, which incorporate a single idler weighbridge and dust-proof load-cell, have bridge capacities from 20 to 20,000 tons/h. Manufactured by Electroweighers (Birmingham) Ltd.

Circle **No 545** on reply card

Transistorized inverters designed to replace rotary inverters in aircraft are available with a variety of outputs. In the 115 V output inverter the range extends from 75 to 750 VA at 400 c/s, and in the 230 V output models from 75 to 600 VA at 50 c/s. Made by Elliott Brothers, units can be supplied for inputs of either 24 or 28 V d.c. Frequency stability is given as 1% of nominal at 25°C.

Circle **No 546** on reply card

Low-noise-level chopper relays have been developed to detect signals of rather less than 100 μV peak to peak. The makers, Ericsson, claim that noise level is reduced to about 50 μV, measured with a load of 1 MΩ.

Circle **No 547** on reply card

Oil detector. An instrument to detect presence of oil on water has recently been developed. It operates by means of a capacity-sensitive detector located in an interceptor tank through which the water flows. Made by Smiths Industrial Instrument Division.

Circle **No 548** on reply card

Variable-flow in-line pumps enable flow to be controlled from zero to maximum capacity. Range is 10 gal/h to 50 gal/min at pressures from 10,000 lb/in² to 2000 lb/in² for the larger pumps. The makers are Sutcliffe Hydraulics.

Circle **No 549** on reply card

Squirrel-cage motors. A range of fan-cooled squirrel-cage motors with class E insulation is introduced by G.E.C. These 'D' frame machines are available up to 7½ h.p. at 1500 rev/min and 5 h.p. at 1000 rev/min. Ratings are in accordance with B.S. 2613.

Circle **No 550** on reply card

Power supply. Transistorized dual-range supplies provide either 0–18 V at 2 A, or 0–36 V at 1 A. Line and load regulation are 10 mV and 5 mV respectively, ripple being quoted as 0·2 mV r.m.s. Two units may be mounted side by side in a 19 in. rack, and may be operated in series or parallel as required. Model TP-36/18 is made by Invar Electronics.

Circle **No 551** on reply card

Butterfly valves claimed to be usable for high-vacuum work are constructed from stainless steel by Edwards High Vacuum. The QSB range covers from a 1 in. bore valve for maual operation, and 2, 4, and 6 in. bore models available for either manual or pneumatic operation.

Circle **No 552** on reply card

INDUSTRIAL PUBLICATIONS

Scientific instruments. Catalogue 'N' from W. G. Pye has 32 pages covering a wide range of products.

Circle **No 553** on reply card

Fuel flowmeter. An integrating indicator for aircraft use is described in leaflet A/19 from Negretti & Zambra.

Circle **No 554** on reply card

Power system protection. A 10-page booklet from English Electric describes their transistorized V.F. intertripping system.

Circle **No 555** on reply card

'Current Collection' is the title of pamphlet ZD 37, showing carbon current-collectors made by Morgan Refractories.

Circle **No 556** on reply card

Liquid blending is the subject of a booklet (AB201) from Constructors John Brown, showing their 'auto-blender'.

Circle **No 557** on reply card

Automatic controllers are detailed in a 16-page booklet (No. R30/2E) from Negretti and Zambra.

Circle **No 558** on reply card

'The case for coal' is the title of an illustrated booklet issued by the National Coal Board.

Circle **No 559** on reply card

Semiconductor devices. A pamphlet entitled 'Designers Guide' from Mullard details semiconductors for industrial equipment.

Circle **No 560** on reply card

Core memories are described in a leaflet from Telemeter Magnetics (U.S.A.).

Circle **No 561** on reply card

Capacitance transducers and associated equipment are shown in publications T2 and T5 from Grunther Industrial Development.

Circle **No 562** on reply card

Power transistors, *n-p-n* silicon diffused, are detailed in data sheets 2SO12A and 2SO13A (issue 1) from Texas Instruments.

Circle **No 563** on reply card

Air control valves are illustrated in a pamphlet from Stuart Davis.

Circle **No 564** on reply card

Silicon diodes are listed in a short catalogue from International Rectifier (G.B.).

Circle **No 565** on reply card

Oil-retaining bearings. An illustrated catalogue from Birfield Industries.

Circle **No 566** on reply card

Electromagnetic transducers for use in instrumentation control are illustrated in a catalogue from Salford Electrical.

Circle **No 567** on reply card

Flameproof controls are detailed in List No. 179/A from Londex.

Circle **No 568** on reply card

Hall-effect devices are comprehensively described in a catalogue by Siemens and Halske.

Circle **No 569** on reply card

Small electronic components are listed in a general catalogue from A. F. Bulgin.

Circle **No 570** on reply card

We regret that the accuracy of the Analytical Measurement's pH meter shown in April 'New for Control' was wrongly quoted as 0·2 pH. This should have read 0·02 pH.

G.E.C.

LEVEL MEASURING UNIT

APPLICATION

This G.E.C. unit with appropriate probes measures the quantity of liquid or free-flowing granular material in a container. It is particularly useful when more normal methods such as float gauging, sight glass, or weighing techniques cannot be used.

EQUIPMENT

The equipment is fully transistorised, and operates from a 28-volt d.c. supply. The level measuring unit consists of an oscillator, a capacitance bridge, and a detecting amplifier. The oscillator generates a 4kc/s supply to feed the capacitance bridge.
The unit employs the latest printed circuit techniques and the complete assembly is encapsulated in epoxy resin.
This ensures that the unit will withstand severe shock and vibration. Two sockets are provided in the unit, one for a coaxial cable to connect the unit to the container and another to connect the unit to the meter and 28-volt d.c. supply.

SPECIFICATION

Accuracy	0 to + 55°C. ± 2½% −40°C. to + 70°C. ± 5%
Power Supply	24 volts d.c. ± 4 volts
Consumption	50mA
Distance between unit and container	15 ft. maximum
Dimensions	3¼ × 1¾ × 2 ins. 8.21 × 4.45 × 5.08 cms.
Weight	18 oz., .51 kg.
Temperature range	−40°C. to + 70°C. with 100% relative humidity

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Book Reviews

Digits

Digital and Sampled-Data Control Systems *by* **Julius T. Tou.** *McGraw-Hill. 1959. 631 pp. £5 16s 6d.*

In general the book presents and illustrates a comparatively new subject very well. It is largely theoretical, as is inevitable for a work intended to be a textbook for degree students. However, there is a good deal of practical technique outlined, particularly with regard to analogue-to-digital conversion and general design principles.

The author commences by clarifying the difference between sampled-data and true digital systems. The theory of the z-transform, necessary in order to rationalize the effect of sampling of essentially continuous systems, is well developed, with repeated reference to the z-plane in which the design is performed.

Synthesis of the digital controller to stabilize and to achieve the desired total response is rigorously dealt with. The error coefficients could have been developed so as to incorporate performance criteria based on them, e.g. the sum of the r.m.s. error coefficients reduce to zero.

Finite pulse-width systems are dealt with thoroughly. The chapter on continuous systems seems somewhat out of place. On the other hand, it forms a useful adjunct for the student as well as for those starting in the art of cybernetics.

This is one of the early works on the subject of digital systems, and sets a high standard as a useful textbook and reference for the practising engineer. W. L. MARKS

Computers

Handbook of Automation, Computation, and Control. Volume 2 : Computers and Data Processing *by* **E. M. Grabbe, S. Ramo** *and* **D. E. Wooldridge.** *Chapman & Hall, London : John Wiley, New York. 1959. 1071 pp. £7.*

Like big computers, as well as disgorging a great deal of information this book produces a great deal of hot air. However, it possesses certain merits. In particular, the opening chapter on computer terminology and symbols, carefully selected from the I.R.E. and A.C.M. definitions, must rank as one of the best glossaries so far produced; although only 22 pages long, this makes the whole book worth having—and almost makes it possible to read the rest of the book. The second chapter, on digital computer programming, starts extremely well, but, like so many texts on programming, degenerates into the particular details of specific machines. Needless to say they are all American, except Soviet Strela—one cannot help wondering what those foreigners will think of next! Although it is very tiresome to read, this monster chapter (265 pages) contains a lot of valuable information on the subject.

Chapters 3 to 11 are grouped in a section headed *The Use of Digital Computers and Data Processors*. These range over the scientific, business, and non-numerical fields, the latter subject being covered by articles on game-playing, language-translation and literature-searching applications. This section, despite the title, starts with data processing and finishes with digital computers, which, for a book based on logic . . .?

The next section, comprising chapters 12 to 20, deals with the design of digital computers, and starts with a chapter on the fundamentals. This is almost a repetition of the early part of the book, and, with more careful editing, would have been omitted. The rest of the section is on design techniques for thermionic, solid-state, and magnetic circuitry, and includes display and read-out equipment. Although suffering in some measure by being rather too particular in quoting actual component types and values, this section provides a wealth of information and experienced comment.

The following eight chapters cover the design and application of analogue computers. Chapter 21 discusses, at a very low level, the methods and classification of analogue systems, the areas of application of such techniques, and the symbols used. Linear and non-linear elements are dealt with in the following two chapters, and the effects of imperfect amplifiers (e.g. drift, finite gain, bandwidth, etc.) are cursorily mentioned. Apart from a useful table of some forty transfer impedances of operational amplifier networks, these chapters are mediocre, and the original textbooks from which most of this material has been taken should preferably be read at first hand. Nevertheless, it is pleasing to see references to Wass, Thomas and Squires, all of whom have made major contributions to the analogue art in the U.K. Chapter 24 is a clearly written introduction to analogies and duals of physical systems. The point is made that no dual can be found if the original system is non-planar, but planar is not defined; which may well puzzle those not familar with this network-theory concept. Furthermore, there is no guide on how to handle mixed physical systems such as electromechanical relays and other transducers. This is a serious omission, since it is here that so many mistakes in the application of the principles of duality can occur. Note that this chapter, the key to the handling of all lumped-parameter systems, is dismissed with no reference to d'Alembert or Firestone in only thirteen pages and seven references. Chapter 25, on field problems, covers the subject, techniques and methods in 23 pages, and is again merely a brief guide.

Noise and statistical techniques in the next chapter are presented with simple theory, and some noise generator designs are described. Mechanical computer elements come next in chapter 27, followed by an elementary description of d.d.a. systems in chapter 28. The final three chapters form a section called *Unusual Computer Systems*, and deal with hybrid computers employing both digital and analogue techniques, and, lastly, the use of Turing-type computers which can imitate the logic of other digital systems.

Volume 2 is disappointing after Volume 1,* which, by comparison, is an excellent source-book and finger reference. It appears that the task of producing a really good handbook on computers is still an insuperable one. The book is unbalanced in style, too often repeats material from previous chapters or Volume 1, and is mostly too superficial to be more than a broad commentary on the rat-race world of computers.

K. C. GARNER

**Reviewed in* CONTROL *for May, 1959, by N. Ream.*—EDITOR.

Books Received

Lichtempfindliche Bauelemente fur die Automatisierung *by* **Paul Goercke.** *R.v. Decker's Verlag, Hamburg. 1960. 312 pp.* ★ 701

Economic Control of Interconnected Systems *by* **Leon K. Kirchmayer.** *John Wiley & Sons Inc. 1959. 207 pp. £5.* ★ 702

Automation. *International Labour Office. 1960. 27 pp.* ★ 703

Industrial Instrument Servicing Handbook *by* **G. C. Carol.** *McGraw Hill Publishing Co. 1960. 540 pp. £4.* ★ 704

Servomechanism Practice *by* **W. R. Ahrendt** *and* **C. J Savant.** *McGraw Hill Publishing Co. 1960. 566 pp. £4 17s.* ★ 705

The Engineer Buyers' Guide 1960. *Morgan Bros (Publishers) Ltd. 1960. 976 pp. 7/6.* ★ 706

Encyclopædia on Cathode-Ray Oscilloscopes and their Uses *by* **J. F. Rider** *and* **Seymour D. Uslan.** *Chapman & Hall Ltd., London: John Wiley & Sons, New York. 1959. 1337 pp. £10 10s.* ★ 707

Industrial Electronics and Control *by* **G. Kloeffler.** *Chapman & Hall Ltd., London: John Wiley & Sons, New York. 1960. 540 pp. £4.* ★ 708

Fundamentals of Electronics *by* **E. Lurch.** *Chapman & Hall Ltd., London: John Wiley & Sons, New York. 1959. 631 pp. £3 6s.* ★ 709

Reciprocals of the Integers from 1000 to 9999 *by* **T. H. Redding.** *Taylor & Francis Ltd. 1960. 43 pp. 18/6.* ★ 710

The Other Side of the Moon. *Translated from the Russian by* **J. B. Sykes.** *Pergamon Press. 1960. 40 pp. 10/6d.* ★ 711

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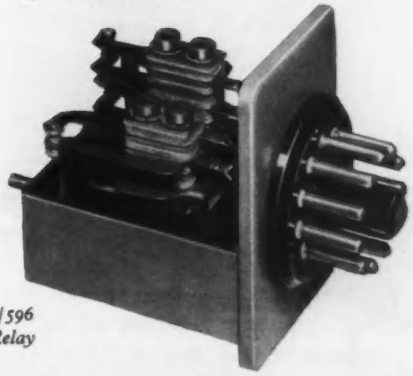

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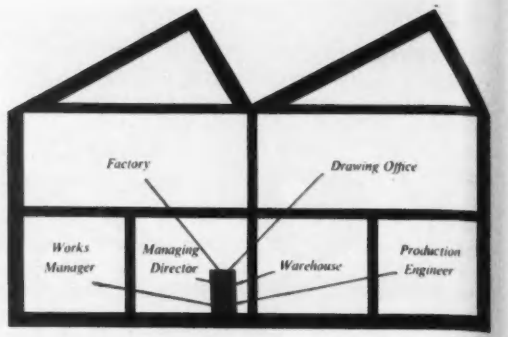

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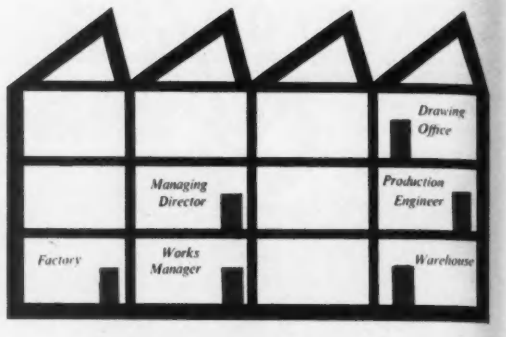

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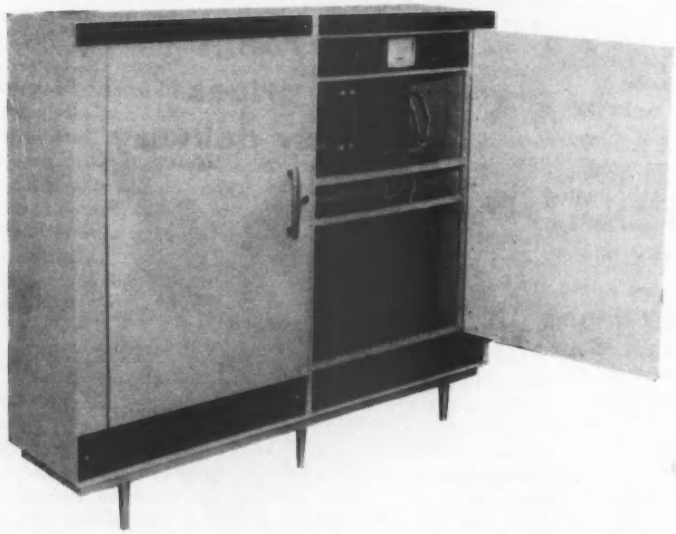

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- ★ **ONLY 0.5 in diameter, 0.5 wattage rating and ONLY 7 grammes in weight.**
- ★ **A wide resistance range of 10 ohms — 10,000 ohms.**
- ★ **Resistance accuracy of ± 5% as standard.**
- ★ **High end stop torque.**
- ★ **Facilities for increasing operating torque.**

Full electrical and mechanical details are given in Data Sheet No. 10 available on request.

Available in two versions, one for standard wiring circuitry, the other for printed circuit application with locating centres 0.2 in apart, both versions are ideal for transistorized equipment etc.

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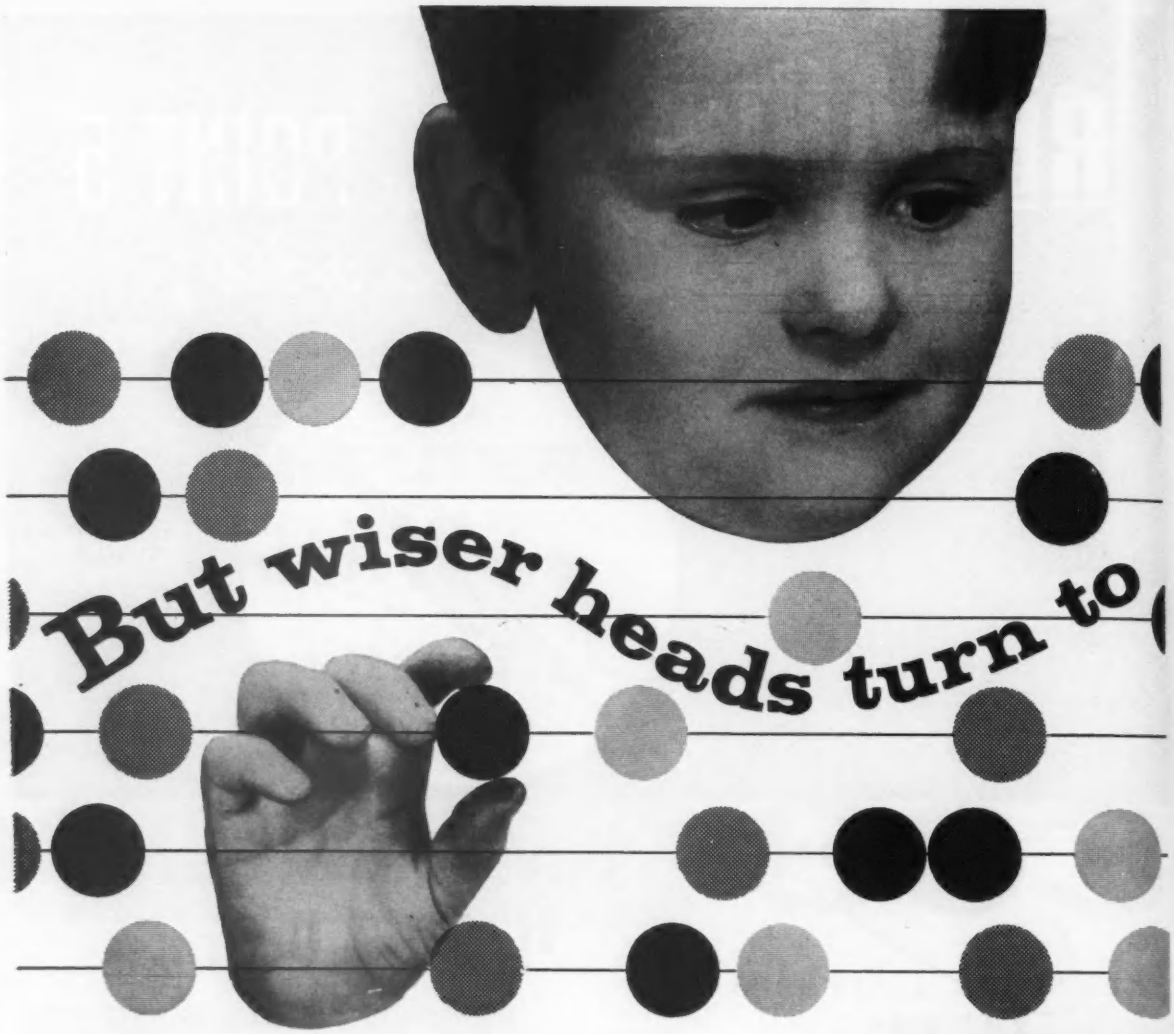
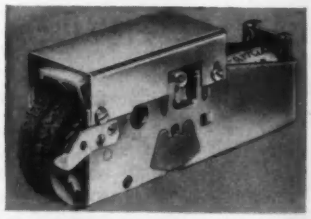
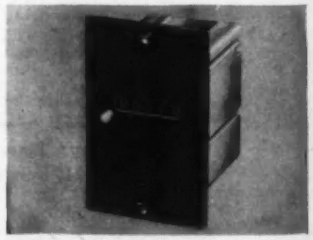


TMC Elmeg Counters are as near perfect as they can be made by the human skills of technical experts with years of experience and the most advanced equipment at their disposal. As a range, they are exceptionally versatile — offering a choice which should match up to even the most remote requirements. Available in "Print-Out" and "Read-Out" form, they have fast operating speeds of up to 40 per second. They operate on up to 220 Volts, with uni-directional or bi-directional motions. Re-setting to zero by electrical and mechanical methods. There are auxiliary contacts operating on each revolution of a number wheel. The range includes counters for flush panel mounting and surface mounting. No special servicing is required.



ZDmh—An 0-24 hours print-out counter for vertical mounting



PZ5elR—5-digit counter with electrical and mechanical reset.

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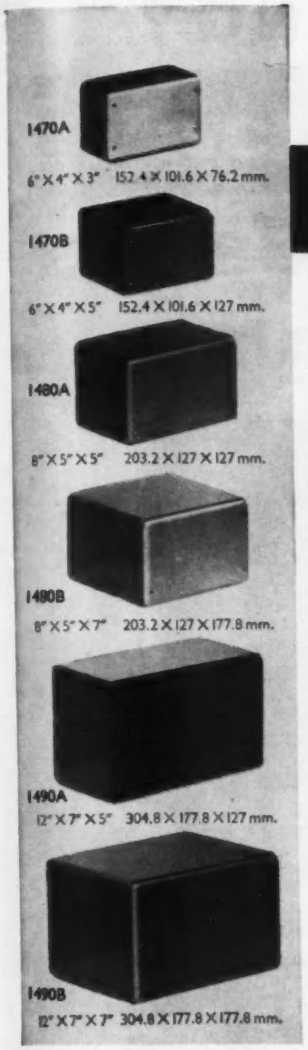

NOW—9 new ultra-miniature cases—MINIBOXES—of 2-piece construction. From 3" x 1⅛" x 2¼" to 17" x 4" x 5". Details on request.

JETZT — 9 neue Ultra-Miniaturgehäuse — MINIBOXES — zweiteilige Ausführung. Grössen von 76 x 41 x 54 mm bis 430 x 100 x 125 mm. Einzelheiten auf Anfrage.

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AHORA — 9 nuevas cajas ultraminiatura — MINIBOXES — de construcción en dos piezas. Desde 76 x 41 x 54 mm hasta 430 x 100 x 125 mm. Detalles sobre demanda.

15 new Imhof standard cases—panel sizes from 6" x 4" to 24" x 10½". Just look at these examples—and the new low prices! All are built to the same robust specification and high finish as the existing Imhof Standard Range. The cases are of two types: with sloping front panels, and rectangular cases with vertical front panels. All available in standard duo-tone finishes. And Imhofs have produced a new chassis incorporating fixing brackets especially for these cases!

Neuartige kleine genormte Gehäuse zu NIEDRIGEN PREISEN

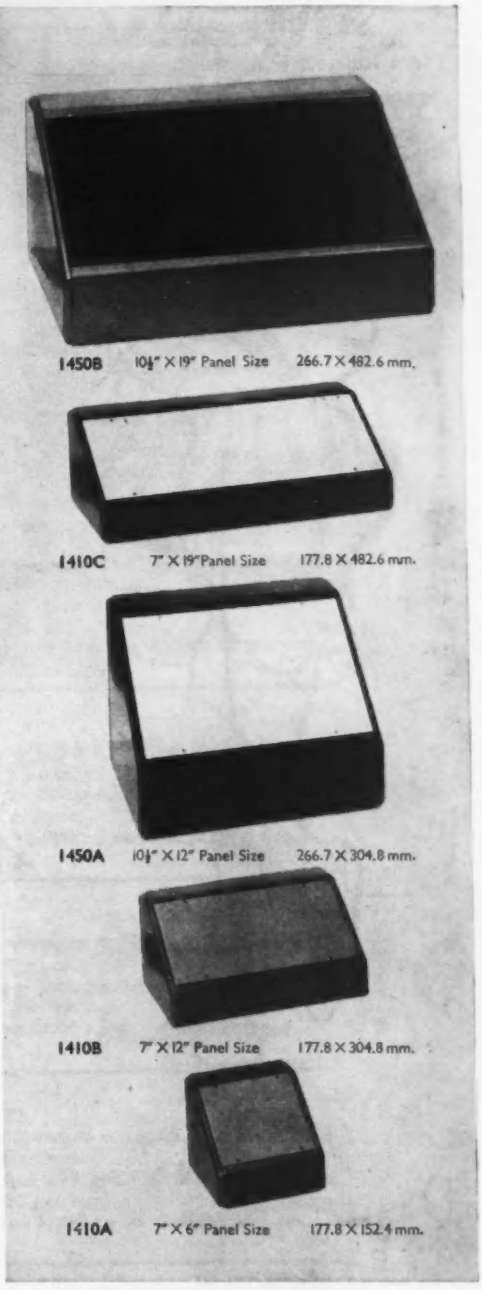
15 neue genormte Imhof-Gehäuse—Wandgrössen von 150 x 100 mm bis 610 x 265 mm. Beachten Sie bloss diese Muster—und die neun niedrigen Preise! Sie sind alle in gleicher robuster Bauart und derselben hochwertigen Fertigung ausgeführt wie die schon bestehende Imhof-Normalreihe. Die Gehäuse sind in zwei Typen erhältlich: mit geneigter Vorderwand und in rechtwinkliger Ausführung mit vertikaler Vorderwand. Alle lieferbar in standard-Zweifarbentönung. Imhof hat überdies für diese Gehäuse ein neues Chassis samt Befestigungsstützen herausgebracht!

Nouveaux boîtiers normaux de petit format à des PRIX INFERIEURS!

15 nouveaux boîtiers normaux Imhof—grandeurs de panneau allant de 150 x 100 mm à 610 x 265 mm. Regardez dont ces exemples et les nouveaux prix inférieurs. Tous sont fabriqués d'après la même spécification rigoureuse et le même fini de haute qualité que l'on trouve dans la Gamme Normale Imhof. Les boîtiers tombent dans deux catégories: ayant des panneaux avant en pente, et des boîtiers rectangulaires ayant des panneaux avant verticaux. Tous peuvent être obtenus avec des finis normaux à deux couleurs. Et la compagnie Imhof a spécialement fabriqué un nouveaux châssis comportant des appliques de fixation pour ces boîtiers!

Nuevas cajitas normales a PRECIOS REDUCIDOS

15 nuevas cajas normales Imhof, con tamaños de panel comprendidos entre 150 x 100 mm y 610 x 265 mm. ¡Vea esos ejemplos y los nuevos precios reducidos! Construidas todas ellas con las mismas características de robustez y excelente acabado que son propias del actual Surtido Normal Imhof. Las cajas son de dos tipos: con panel frontal inclinado, y cajas rectangulares con panel frontal vertical. Todas ellas están disponibles con acabado normal en dos tonos. Y la Imhof ha fabricado especialmente para esas cajas un nuevo chasis que incorpora ménsulas de fijación.



Stand H/360 IEA Exhibition Olympia May 23–28

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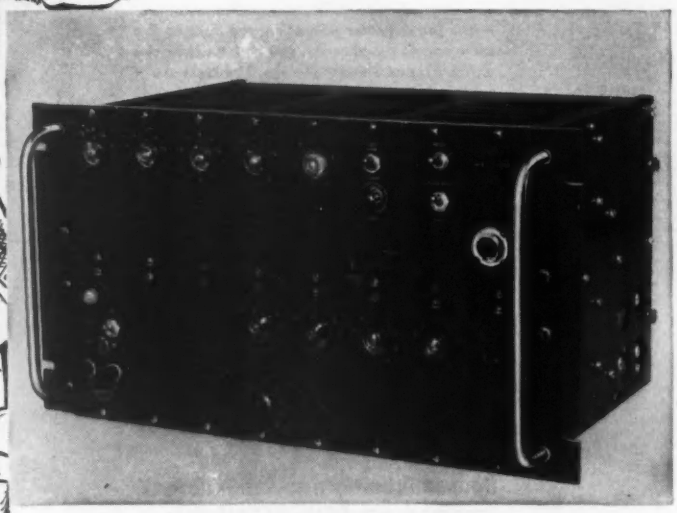
COUNTING?

"MULTIPLICATION IS VEXATION
DIVISION IS AS BAD
THE RULE OF THREE DOTH PUZZLE ME
AND PRACTICE DRIVES ME MAD!"



Tachometer Type 144A—constructed from Plug-in Counting Sub-Units.

The quaint complaint of the Elizabethan schoolboy might well re-echo today where management have not yet realised the significance of modern digital counting techniques.
Many industrial control problems can be interpreted in terms of counting, timing or measuring. To meet these requirements we have introduced a wide range of inexpensive plug-in counting sub-units. These units, of which there are over 50, can be combined to produce dependable equipment for applications ranging from simple counting and batching to complex digital control.
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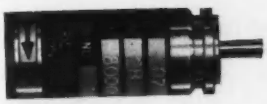

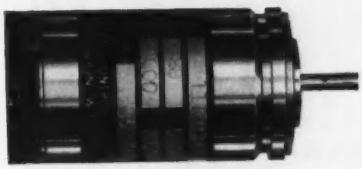

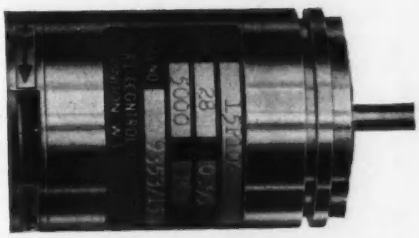

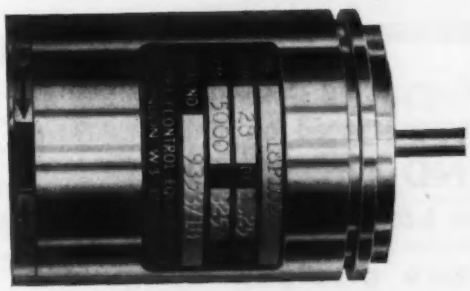

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Torque 50 gm. cm. Min. stall torque 100 gm. cm.
Speed 5,000 r.p.m. Weight 60 gm.

SIZE 11.
Std. voltages 6, 12, 28. No load speed 8,500 r.p.m.
Torque 120 gm. cm. Min. stall torque 270 gm. cm.
Speed 5,000 r.p.m. Weight 145 gm.

SIZE 15.
Std. voltages 6, 12, 28. No load speed 7,500 r.p.m.
Torque 220 gm. cm. Min. stall torque 650 gm. cm.
Speed 5,000 r.p.m. Weight 305 gm.

SIZE 18.
Std. voltages 6, 12, 18. No load speed 7,000 r.p.m.
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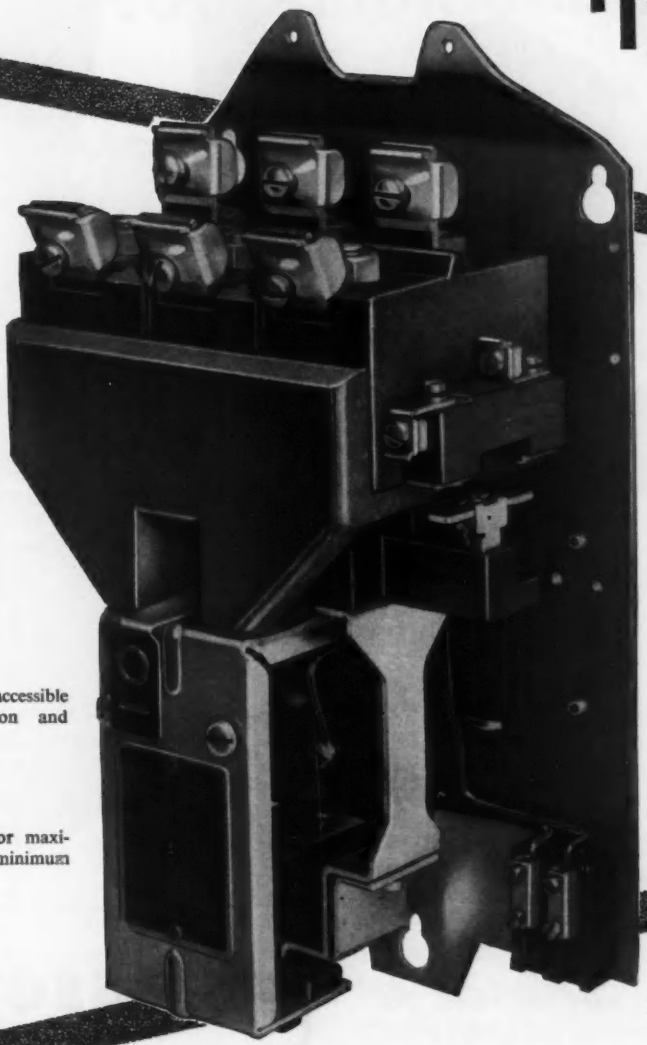

★ Complies with relevant British Standard Specification (frequent duty).

★ Modern design gives robust yet simple construction combining reliability in service with exceptionally long operating life.

★ All parts readily accessible for easy installation and inspection.

★ Silvered contacts for maximum life and minimum maintenance.

★ Clamp type solderless terminals for rapid connection.

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★ Complete range of thermal overload units available.

★ Can be supplied as shown or fitted in wall mounting steel or cast cases.

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MK Contactors
are available from stock in 15, 25, 60 and 100 ampere ratings for a.c.

Control Coils
can be supplied for a wide range of a.c. and d.c. voltages.

Auxiliary Contacts
can be fitted to all sizes of contactors.

For long and trouble-free operation specify L.D.N. Contactors.

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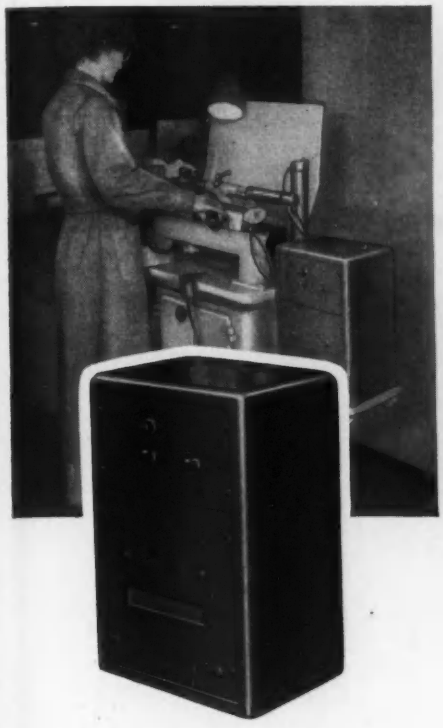

fixed programme controller
for simple applications.
Shown here as an operator's aid
on a commutator trimming lathe.

flexible programme controller
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Shown here applied to a Ward No. 2
capstan lathe for unattended operation.

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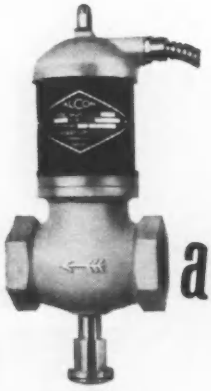
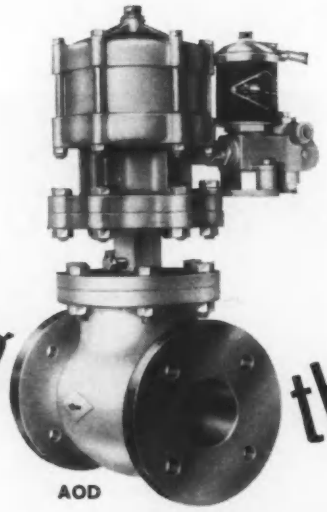
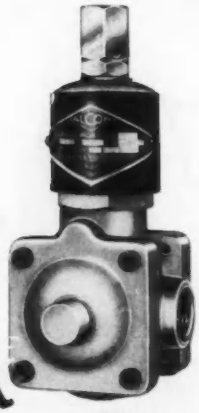


ACH

anything that flows



AOD



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MIDGET Type ACO—Sizes up to $\frac{1}{4}$" B.S.P., used for control of Air, Gases, Water, Oil at pressures up to 300 p.s.i. Single way—Reverse acting—three-way types available.

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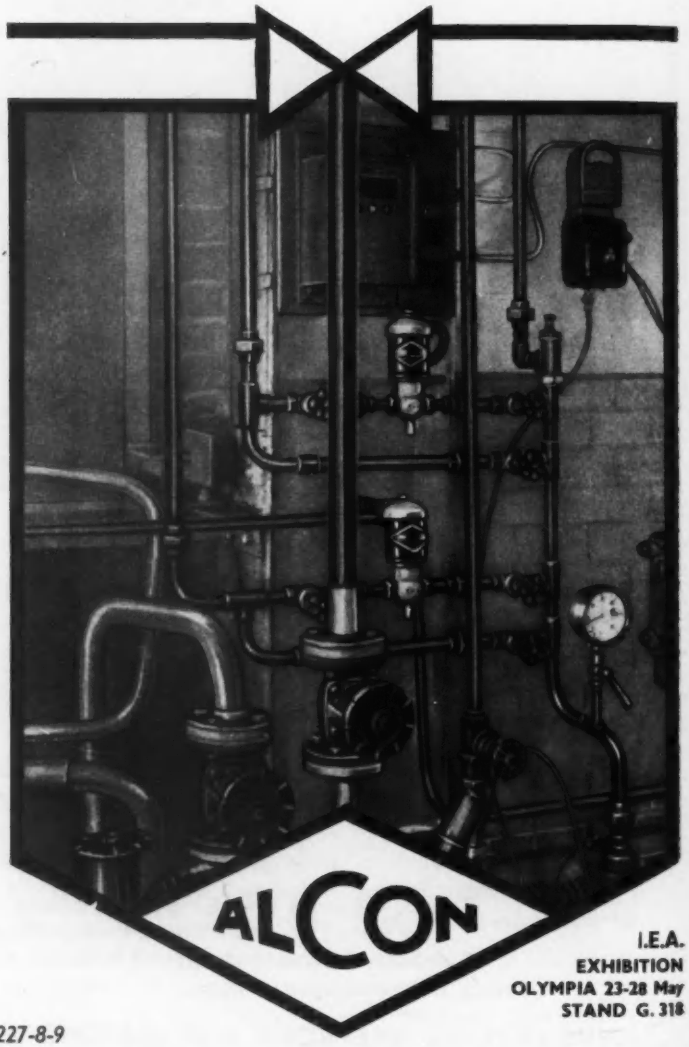

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OLYMPIA 23-28 May
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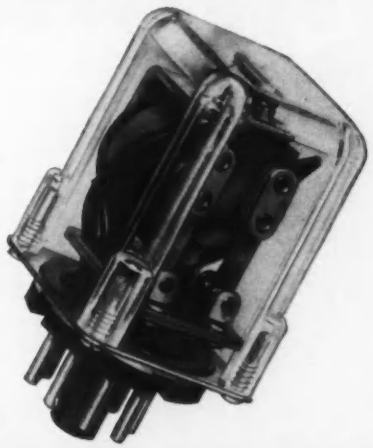
Thorn Pygmy Power Relay



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Dust proof—transparent plastic cover.

Plugs into any standard International octal valve base.

Weight Only 4½ ozs . . . projection only 2" above base.

Mechanical life over 10,000,000 operations.

Switching current: 5 amps maximum at 250 volts A.C.

Maximum surge current: 10 amps.

Operate time: 8 milliseconds approx.

Release time: 6 milliseconds approx.

Overall dimensions: 1⅛" square by 2$\frac{9}{32}$"

Coil voltage: 240 volts standard; also available for 6, 12, 24, 48, 60, 110 volts

Thorn T9 Micro-Switch Relay

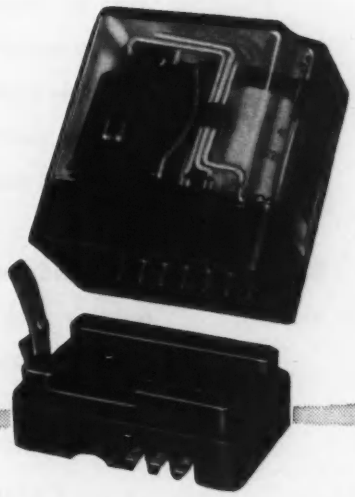
A plug-in relay, particulary suitable for switching P.A. equipment, the snap action contacts minimising interference with pick-up leads.

Operating coil wound for any specified voltage up to 240 volts A.C. or 150 volts D.C. May be tropicalised.

Up to three micro-switch pattern contacts mounted on standard coil frame.

Versions available with up to 11 solder tags or 10 screw terminals.

Contacts:	3 changeover.
Mechanical Life:	Over 10,000,000 operations.
C/O Time:	C.O. period less than 2 milliseconds.
Max. Switch:	10 amps/240 volts A.C. non inductive load.
Capacity:	0.2 amps/240 volts D.C. „ „ „ 0.5 amps/110 volts D.C. „ „ „ 1.0 amps/50 volts D.C. „ „ „ 5 amps/24 volts D.C. „ „ „
Max. Operate Speed:	20 cycles/sec.
Switching:	Up to 0.1 amp. approx. 20 cycles/sec.
Frequency:	„ „ 1 „ „ 5 „ „ „ „ 5 „ „ 1 „ „ „ „ 10 „ „ 0.1 „ „ (referred to A.C. non-inductive load).



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TCI. TIME AND FREQUENCY MEASURING COUNTER

FREQUENCY MEASUREMENT from 10 to 1,000,000 c/s

TIME MEASUREMENT from 1 μ sec. to 2777 hours

* **PERIOD MEASUREMENT** 1 or 10 periods of input waveform down to 10 c/s

RANDOM COUNTING totalling over any period

OUTPUT TIMING PULSES from 10^{-1} to 10^{6} p p.s.

INTERNAL STANDARD oven controlled 1 Mc/s crystal

STABILITY $\pm$ 1 part in 10^{6} at 25°C

FREQUENCY MEASURING PERIOD 0.1, 1.0 or 10.0 seconds

DISPLAY TIME 1 to 5 seconds or 'hold'

POWER CONSUMPTION 3W (battery), 14VA (mains)

DIMENSIONS length 12", height 9", depth 6", weight 12 lb.

IEE EXHIBITION

STAND No. C107

* **AND NOW—virtually to d.c. with C.A.1 attachment.**

1 Mc/s TRANSISTORISED COUNTER

with full laboratory facilities nett price in U.K. **£335**

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RADIOVISOR EST 1927

Completely New Range!

ETHER SOLENOID VALVES

—illustrated is the Type DF high-performance valve suitable for use over a wide range of pressures

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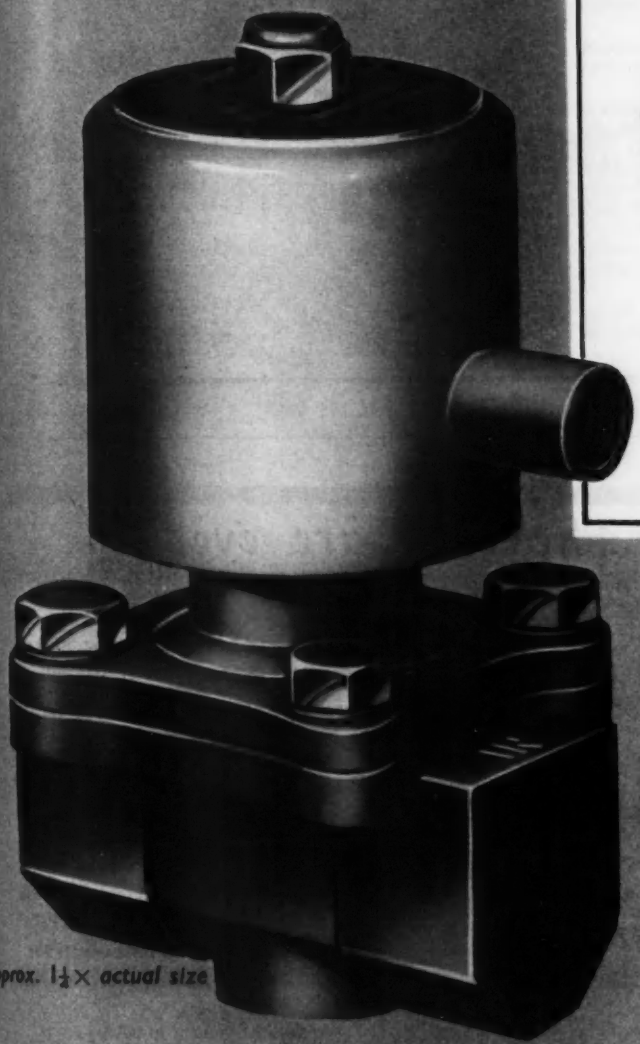

Approx. 1½× actual size

One of the outstanding new range of solenoid valves recently introduced by ETHER LTD., the DF is a pilot-operated diaphragm valve. It is designed for use, over a wide range of pressures, with town gas, propane, butane, water, compressed air, or light fuel-oil. The standard model has ¼" B.S.P. female connections. Non-standard versions can be supplied to order.

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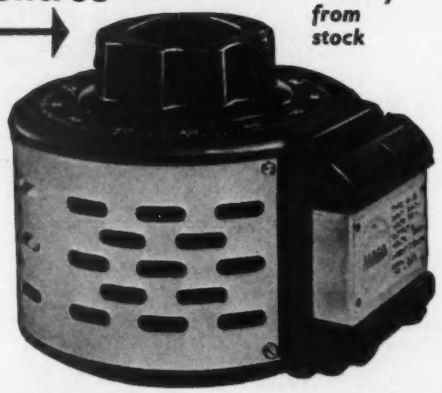

For the most up-to-date variable transformers . . . for early delivery, too, the obvious choice is the Berco Rotary Regavolt, model 42A, rated at 580 V.A. With a maximum input voltage of 250 V. it will supply a variable output from 0-270 V. Moderately priced at £7.0.9*d.* (skeleton type) and £8.5.11*d.* (protected type as illustrated) the Berco Rotary Regavolt represents the finest value today at the lowest cost.

* **CONSTRUCTION:** Toroidally wound auto-transformers, with tracks formed on one face of the windings.
* **CORE:** Wound from a continuous strip of low loss electrical steel in a similar manner to the well-known C core construction.
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* **WINDING:** Of high conductivity copper, insulated with a synthetic enamel of the polyvinal acetal-phenal formaldehyde resin type, giving good space factor, exceptionally high abrasion resistance and prolonged heating resistance.
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* *Write for list 615A giving full technical details of this and other models in the Rotary Regavolt range.*

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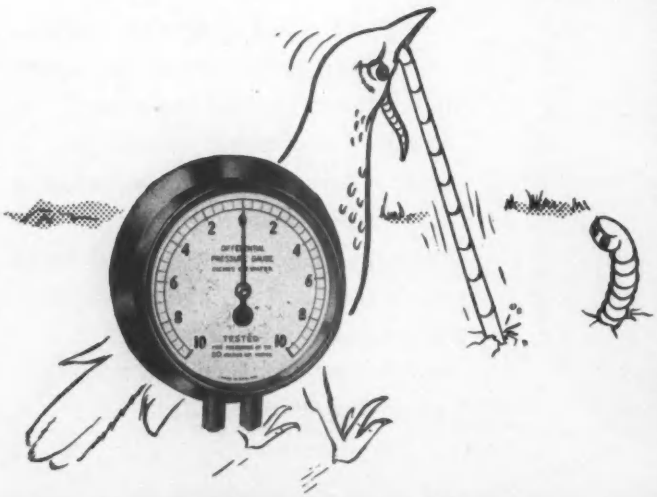

That's how it is just now—but, in the end, the thrush has the greater pull and if it were possible to connect their efforts to a P & G differential pressure gauge, the difference would be evident at once.

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TORQUE AND SPEED CONTROL

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Give you local or remote control positively, simply and precisely.
A TASC master (Torque) gives you full control between zero and rated torque.

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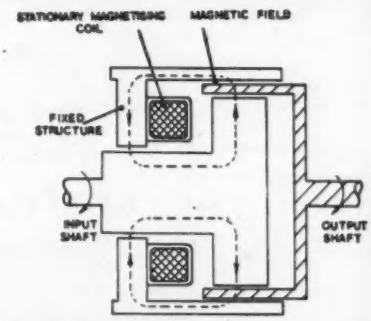
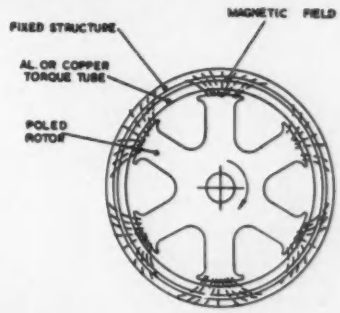


The TASC unit is a new application of the Faraday disc principle.
It consists of two independently rotating members magnetically linked by the field from a fixed coil. The transmitted torque is proportional to the coil current. It is thus an inherently controlled torque device.



The TASC Unit is unaffected by stall-down on output no sliprings or brushes—low output inertia—no out-of-balance forces—sealed bearings—sizes from 1/4 to 10 h.p.

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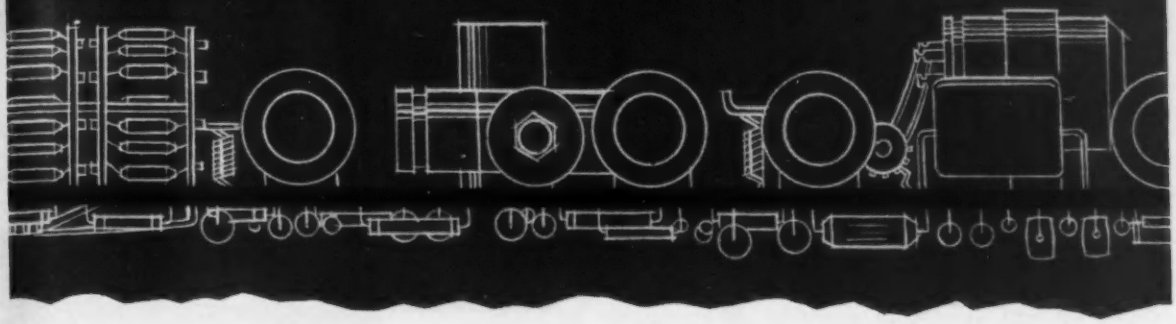
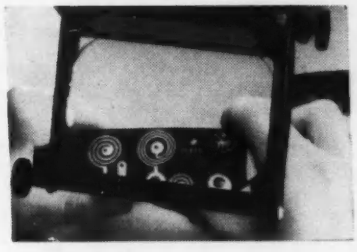
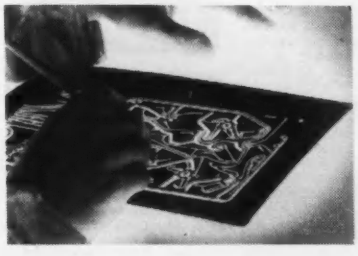


BRIBOND *print circuits faster*



The Printed Circuit is rapidly becoming established assembly practice in every field of electro-mechanics. Meeting this increasing demand takes specialist production such as only Bribond offers. Bribond manufacture circuits complete from design to finished board, and every stage is organised on modern line production methods providing outputs of any quantity. And each individual circuit is subjected to three critical inspections. This is increased when the copper is plated with either rhodium, silver, or gold.

BRIBOND *make prototypes quicker*



The prototype department is at the service of all Bribond customers. It can produce within 48 hours or less, the initial circuit from which future production can be planned. All that is needed is a clean circuit image from which reproduction can be made. Where desired, and time permits, the whole of this work can be carried out in our drawing office. Bribond recognise that quick prototypes—whether for complete units or small sub-assemblies—are essential in these highly competitive days when anything that shortens the time-lag between drawing board and production can mean a big reduction in marketing costs.

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Burgess Hill, Sussex

Telephone: Burgess Hill 85611

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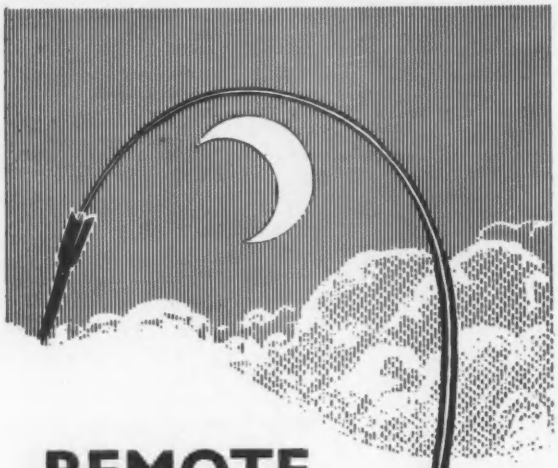

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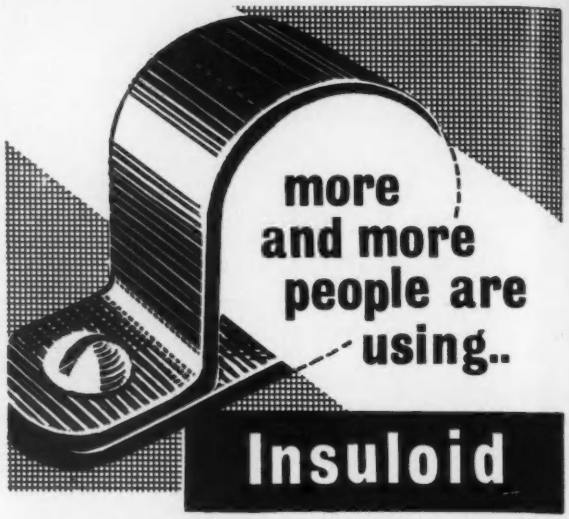

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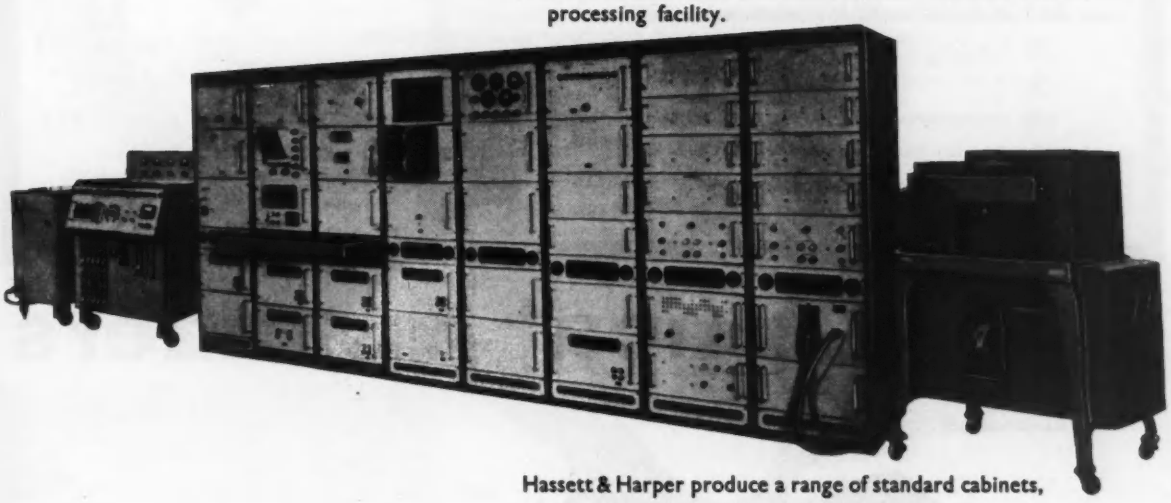

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These meet most requirements, while for very unusual applications, custom-built 'specials' are something our engineers are delighted to produce. Ministry K114 Standard is regularly adhered to.

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INSTRUMENTS, ELECTRONICS AND AUTOMATION EXHIBITION

Olympia, May 23-28

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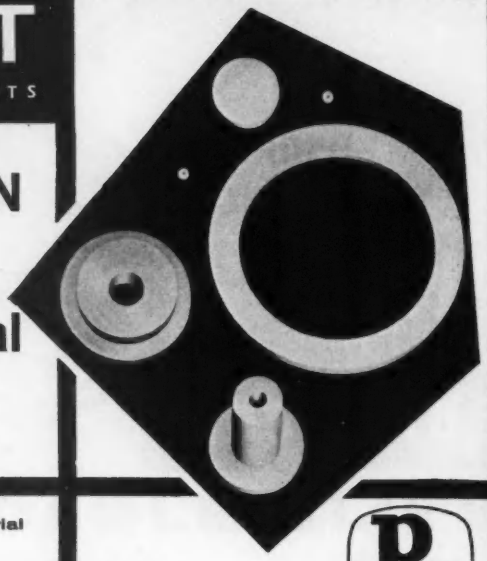
A NEW FLUOROCARBON TFE BASE PRODUCT with improved mechanical and thermal properties



Extensive research has produced a new TFE base material with the following outstanding characteristics:

- ★ low thermal expansion only one sixth that of PTFE
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FLUOROSINT is a trademark — patents pending.

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- Only 3in. in diameter

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It's a comforting thought that a complete wiring system,
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CW 11A

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ON STAND F270
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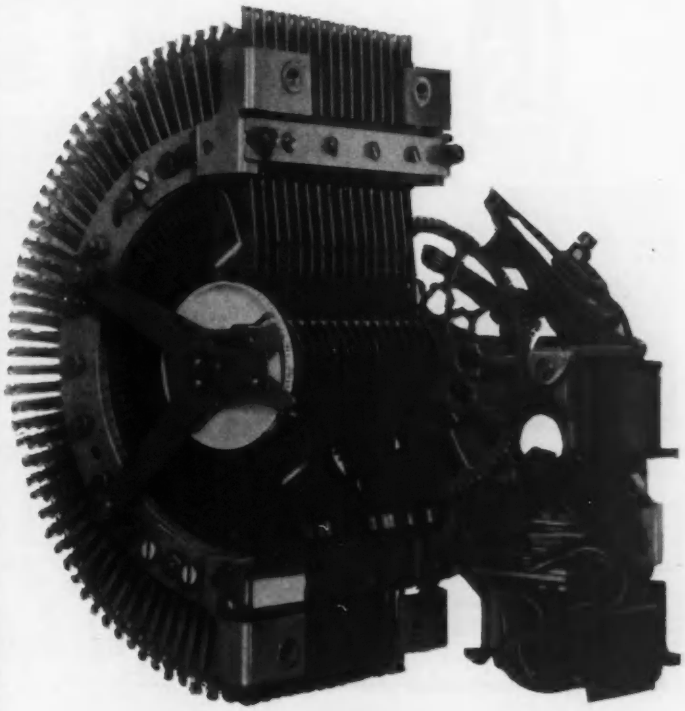
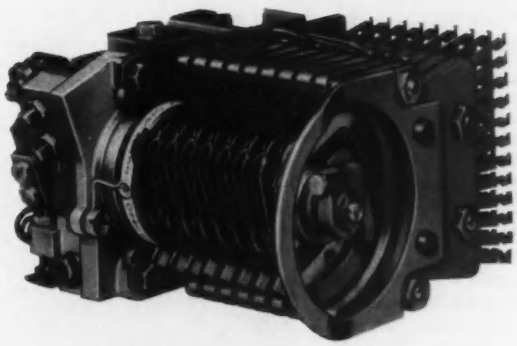
These 3 outstanding uniselectors

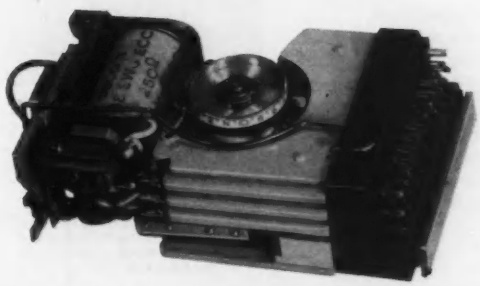
provide long life and reliability in operation



The high speed motor uniselector
has an availability of 52 outlets in a half revolution with up to 16 parallel channels, and is capable of high speed search if required. It is also suitable for scanning and other collection functions, or for the routing of information to a multitude of points. It can be brought to rest at any desired outlet by means of simple circuitry, and a homing drive is provided so that it can be readily restored to the normal position. Arrangements can also be made for step-by-step working.



The digit switch
is specifically designed for step-by-step operation in response to impulses, and has an availability of 12 outlets with 8 parallel channels. It may be used to set up a marking condition for the control of the Motor Uniselector.



The miniature uniselector
is a compact switch of unique design which occupies no more space than a standard 3000-type relay. It has an availability of 12 outlets with 3 parallel channels. A great advantage is that it incorporates a plug-in type of mounting so that the entire device can be removed and replaced without detaching any soldered connections.

AEI

Full technical information will gladly be supplied on application

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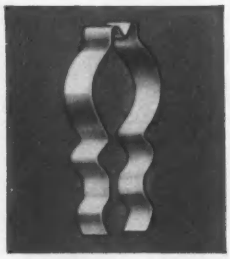
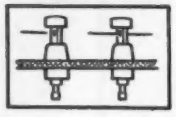
LS products for the Electronics Industry



TRANSISTOR CLIPS
in Beryllium Copper
(Patent and Type Approval applied for)

Of compact design, and taking up no more room than the Transistor itself, these Clips, manufactured from Beryllium Copper and formed so as to assist heat dissipation, are designed to suit cylindrical Transistors such as the Mullard OC.72 for fixing horizontally to printed circuit boards.

Top illustration shows the clip greatly enlarged whilst the lower picture shows the clip actual size and also the method of fixing.



Pressure on the terminal cap opens the transverse hole and allows the wire or pin to be inserted. Release pressure and wire or pin is firmly held in position.

SPRING LOADED WIRING TERMINAL

Designed for mounting on panels up to $\frac{1}{8}$" thick, the terminal accepts wire ends or pins up to $\frac{1}{8}$" diameter and provides a quick and simple connection, secure and proof against vibration. Terminals are available from stock with Black or Red Thermo-plastic fittings or other colours to order.

Ratings :—Current 5 amp. Test Voltage 1000 V., with contact resistance. (Patent and Type Approval applied for).

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Type WFO/1. A 3-stage electronic sequence timer available in a wide variety of models and ranges.

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British Federal

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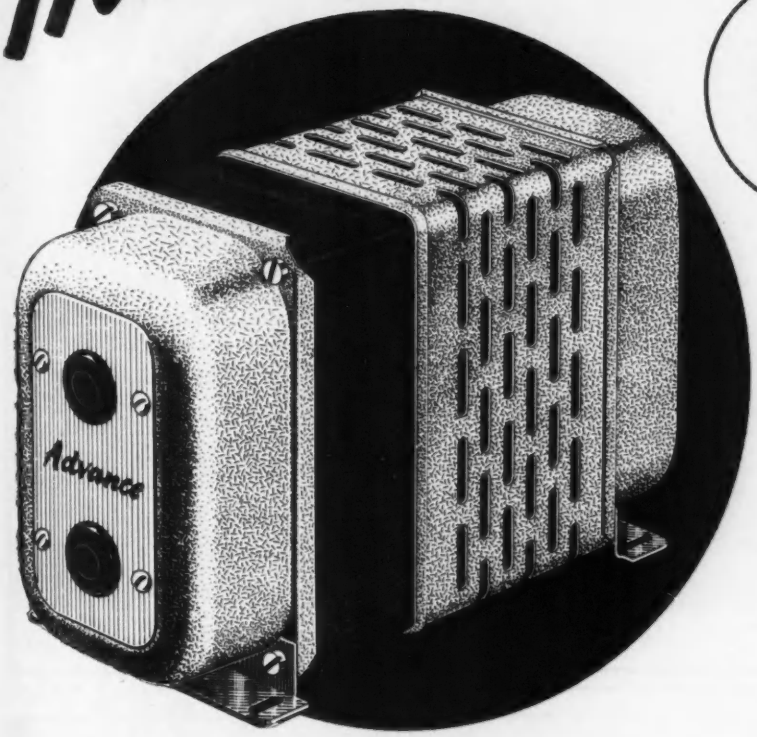

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EXHIBITION STAND NO. C107

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Input Voltage ...	190-260V	190-260V
Output Voltage ...	6V	6V
Output Capacity ...	25W	25W
Dimensions	5½ x 3 5/16" x 4¼"	7" x 5¼" x 4¼"
Weight	5 lb.	7 lb.
	£6. 5. 0.	£8. 0. 0.

Nett prices in U.K.

Full details in Folder M63 available on request.

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Advance COMPONENTS LIMITED

MAINS STABILIZATION DIVISION

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JT.GD 83

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Lock LABORATORY CONDUCTIVITY BRIDGE

This mains-operated instrument has a bridge frequency of 1500 c/s, and covers the very wide range of 0.05 to 1×10^6 micro mhos in seven ranges.

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Industrial bells

The bell illustrated is model 8/225/120, 8" gong, suitable for connection direct to AC mains. Write for leaflet giving full specifications of the complete range.

V&E FRIEDLAND LTD Macclesfield Cheshire

Type F
MINIATURE RELAY

Size:
0.875 in. × 0.8 in. × 0.396 in.

Weight: 0.52 oz.

Operating power:
250 mW nominal.

Pickup: 3.5 mS:

Dropout: 1.5 mS.

Ambient temp:
−65°C to + 125°C.

Vibrations:
5-75 c/s at $\frac{1}{8}$ in. and 75-2000 c/s at 20 G.

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Over 143 models of the type F relay are available in 12 standard coil voltages from 6.3 to 110V d.c. in various mounting arrangements. A typical type F relay of 26.5V has a 675 ohm coil and a minimum operating current of 19 mA, with brackets or 6BA stud fixing and solder hooks or 3 in. lead connectors. Please write or telephone for the Clare Type F Relay Sales Engineering Bulletin No. 124-1, which gives the full technical specification.

C. P. CLARE LIMITED

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A MEMBER OF THE ELLIOTT-AUTOMATION GROUP

Clare relays are made in the United Kingdom under licence from C. P. Clare & Co., Chicago, U.S.A.

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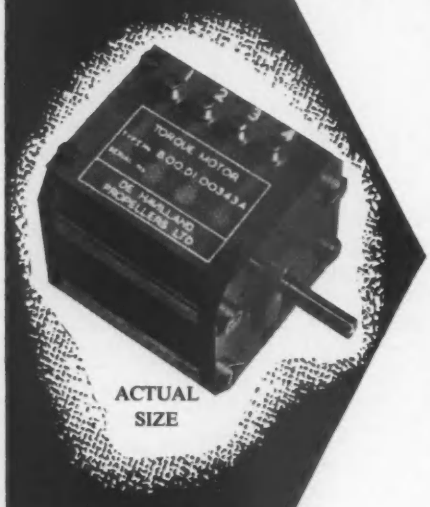
HIGHEST PERFORMANCE — LOWEST COST

DE HAVILLAND TORQUE MOTORS – SERIES 2

Compact, Light, Precision-Built: Suitable for Industrial, Aviation and Missile applications.



The following are characteristics of a typical model from the wide range of de Havilland torque motors:—

(i) Maximum deflection ± 0·15 radians (17° total)
(ii) Maximum torque 1,500 gm. cm. in central position
(iii) Deflection sensitivity 0·0092 radians/mA (differential excitation)
(iv) Torque sensitivity 7·6 gm. cm/mA (differential excitation)
(v) Hysteresis less than 1·5% of amplitude
(vi) Threshold Resolution (Friction Level) — torque motor responds to 0·1% of full scale current
(vii) Natural frequency approximately 500 c/s
(viii) Windings — 2 coils, 510 ohms each
(ix) Vacuum impregnated 1000V insulation
(x) Weight 4·5 oz.

This model has an impedance suitable for differential magnetic amplifier drive and is intended for driving a low stiffness load.
The unit is also available with windings from 10 ohms to 8,500 ohms per coil to suit other types of driver amplifier.
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(a) Outputs up to 2,500 gm. cm. torque with ± 9° travel
(b) Hysteresis below 0·7%
(d) Calibrated as a velocity pick-off having a sensitivity of 6v/radian/sec.

de Havilland Propellers will be pleased to give further information and advice on the use of these torque motors.

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Hatfield, Herts. Tel: Hatfield 2300, Extn. 606

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THE LONDON ELECTRIC WIRE COMPANY AND SMITHS LIMITED

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INTERNATIONAL INSTRUMENTS, ELECTRONICS & AUTOMATION EXHIBITION

OLYMPIA, MAY 23–28

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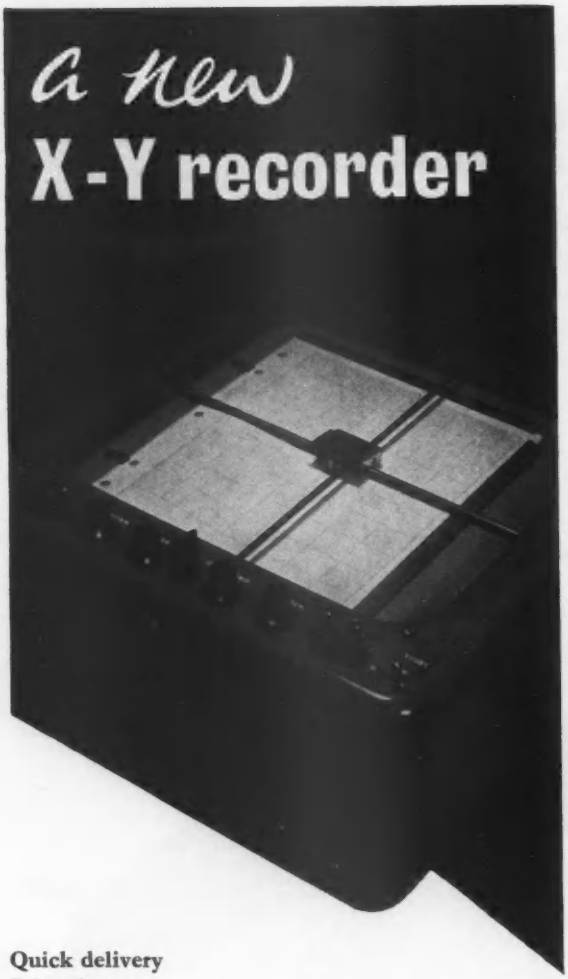
a new X-Y recorder



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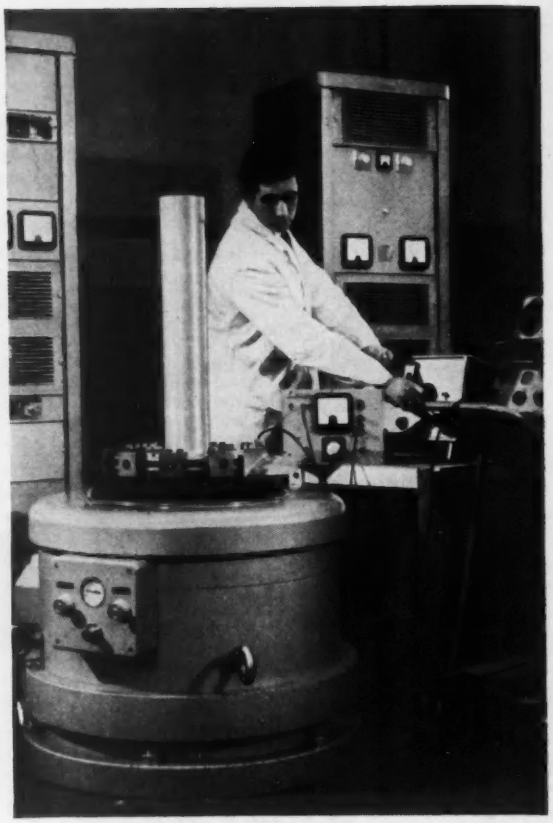

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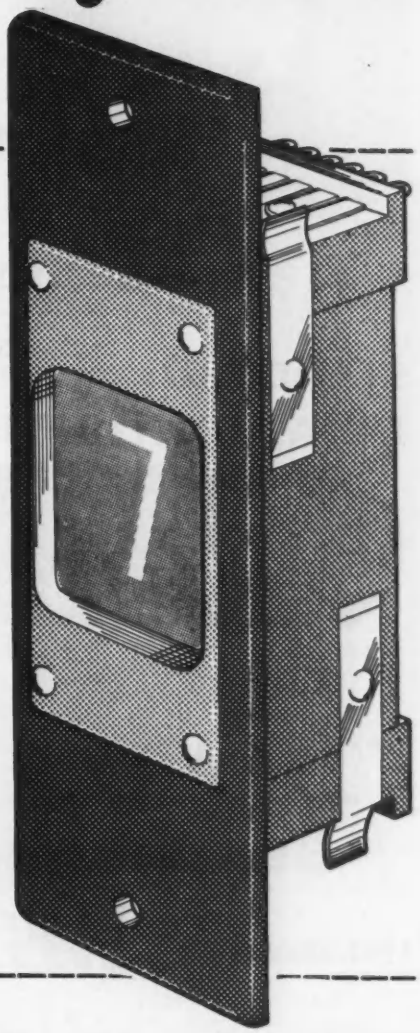
DaS560C

Thorn read-out systems

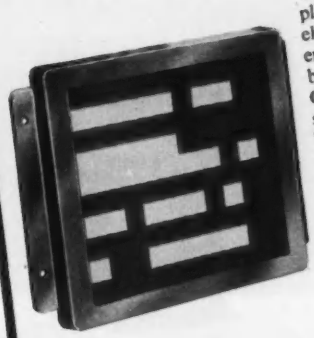
for digital computors



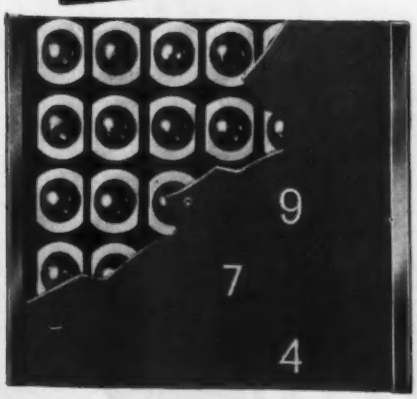
EDGE-LIT INDICATOR

Simple unit structure, easy relamping, robust in-line solder tag connections, 12 circuits. Display includes numerals 0—9 with decimal point (which may be illuminated with two lamps) or with plus and minus signs. Thorn Midget Panel Lamps, in voltage ratings of 28, 12, 6 or 4 (AC-DC) are used to illuminate the characters. Can be supplied separately or with ancillary relay equipment for complete readout system. Overall dimensions $1\frac{1}{8}$″ deep x $4\frac{3}{4}$″ long x $1\frac{3}{8}$″ wide.

ELECTROLUMINESCENT INDICATOR BLOCK

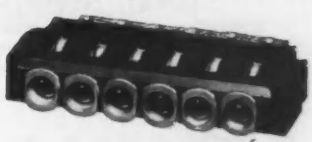


The device is a slim glass plate with an array of 100 electroluminescent spots energised from a printed circuit bonded to the rear face. Characters can be built up by suitable combinations of connections. The current consumed by each illuminated spot is a fraction of a milli-amp, the voltage required being of the order of 300 volts with a frequency range of up to 400 c.p.s. It is available as a separate component or as part of a complete read-out system. Overall dimensions:— 3.500″ x 3.000″ x .265″.



MULTIPLE LAMPHOLDER

When mounted in banks, the Thorn Multiple Lampholder (below) provides a clear legible read-out through variation in the pattern of illuminated Midget Panel Lamps. The bank of Lampholders can be overlayed with a sheet of "Plasteck" on which the desired characters are engraved—each character lining up with one filament. The cut-away illustration (left) shows the read-out system provided by this arrangement. Overall dimensions:—0.430″ x 2.475″ x 1.250″ inc. terminals.



Thorn

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FOR THE DRAWING OFFICE

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TEMPERATURE RANGE:	SERIES BR — 65°C to + 200°C Max. SERIES BS — 65°C to + 125°C Max.
VIBRATION & SHOCK:	Up to 8000 CPS in excess of 20G'S Mechanical shock in excess of 1000G'S
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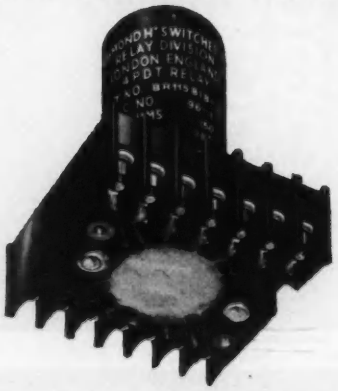
WEIGHT:	4 ozs. Max.
MOUNTINGS:	10 different mountings including plug in and screw and stud terminal block available. General Purpose Relays, Polarised Relays also available



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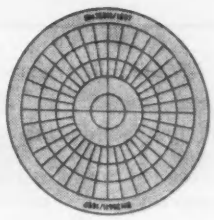
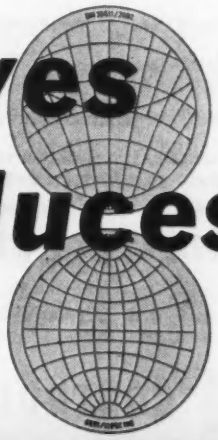
Telephone: Chiswick 6444 Grams: Diamonhart Chisk, London

Z g diagraph



saves engineering time and reduces development costs



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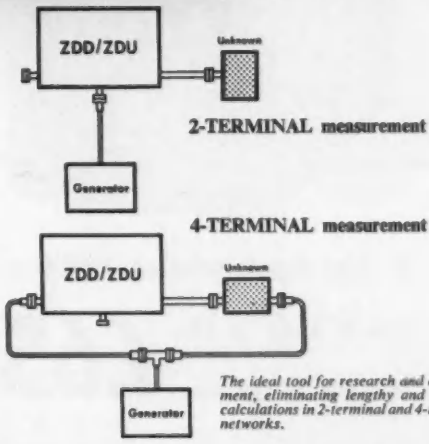

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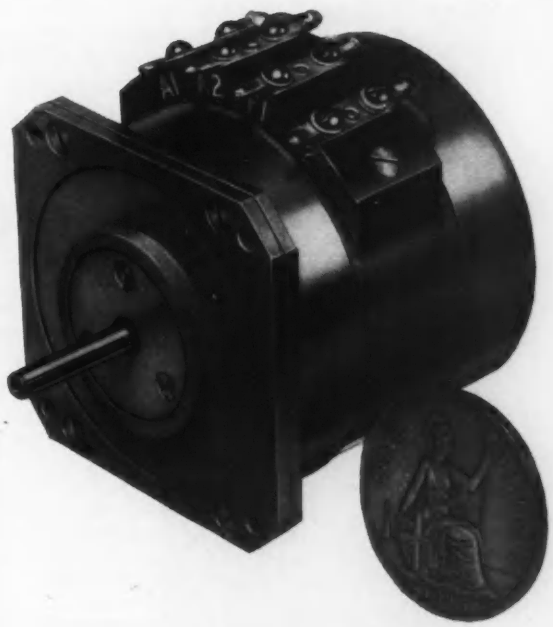

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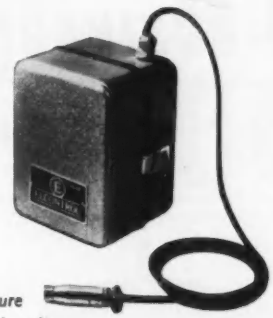
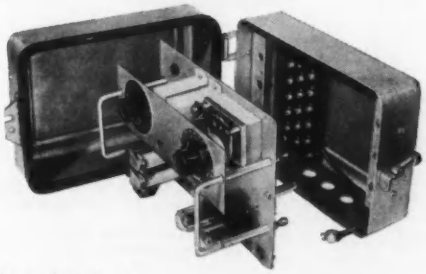


The miniature photoelectric unit

Timing control panel for a large sequence controller



A standard timer showing withdrawable chassis

An ignition sequence and flame failure unit assembled and pre-wired into a complete controller

automation step-by-step

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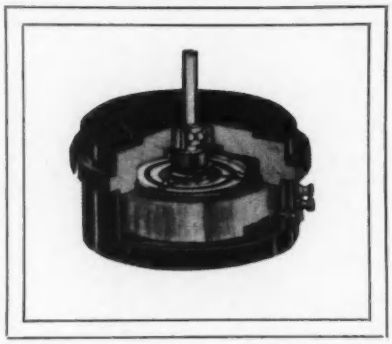
make computers compact



These pots replace gears, cams in data converters and computers. They are **low-inertia,** low-torque, long-life, **low-noise** with special **toroid winding.**

Condensed Specification

Resistance .....20 KΩ per quadrant
Conformity .....1% pk-pk **into 1 MΩ**
Starting Torque.....1 GCM per gang
Angular Accuracy.....± 0.15%
Max. rated Speed.....600 RPM
Inertia .....0.1 GCM^2 per gang
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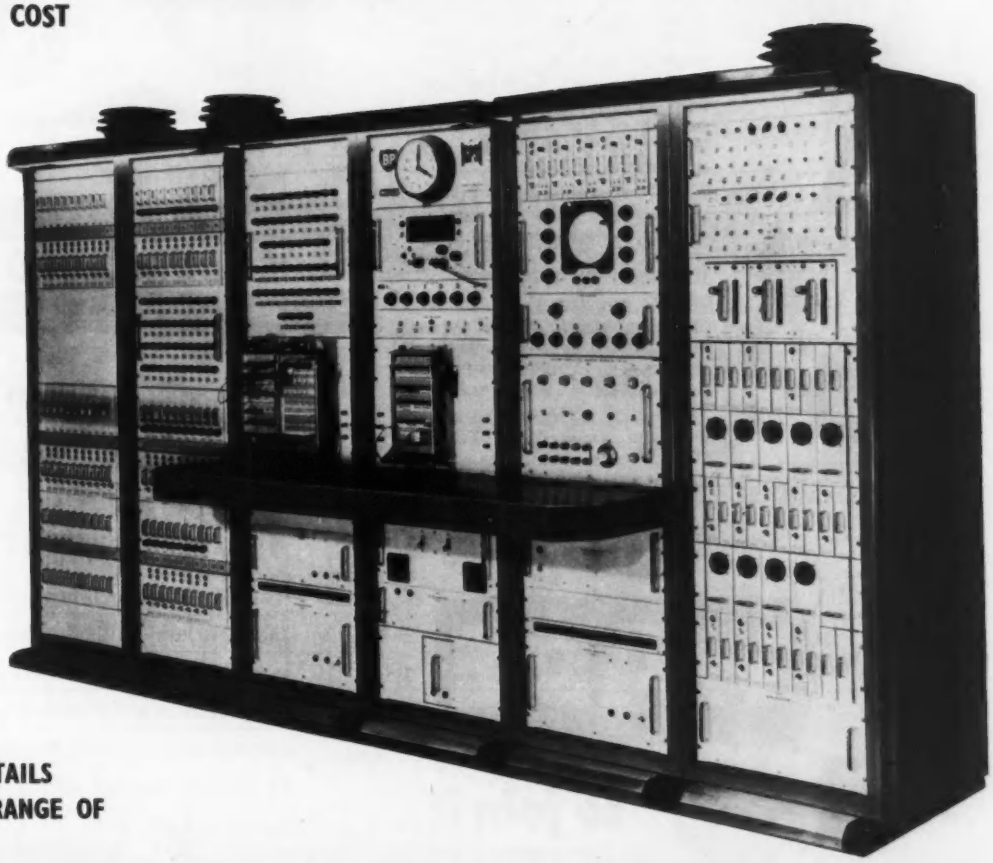

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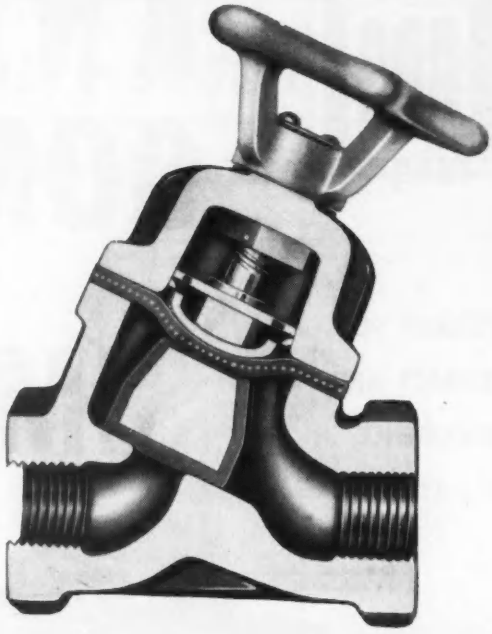

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10 UNIT	19"	$17\frac{1}{2}$"	£1 4s. 6d.	£1 14s. 6d.	12s. 0d.	£1 3s. 4d.
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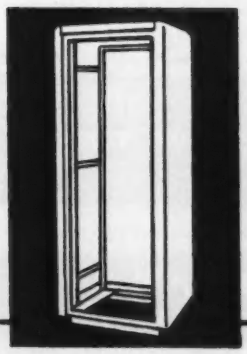

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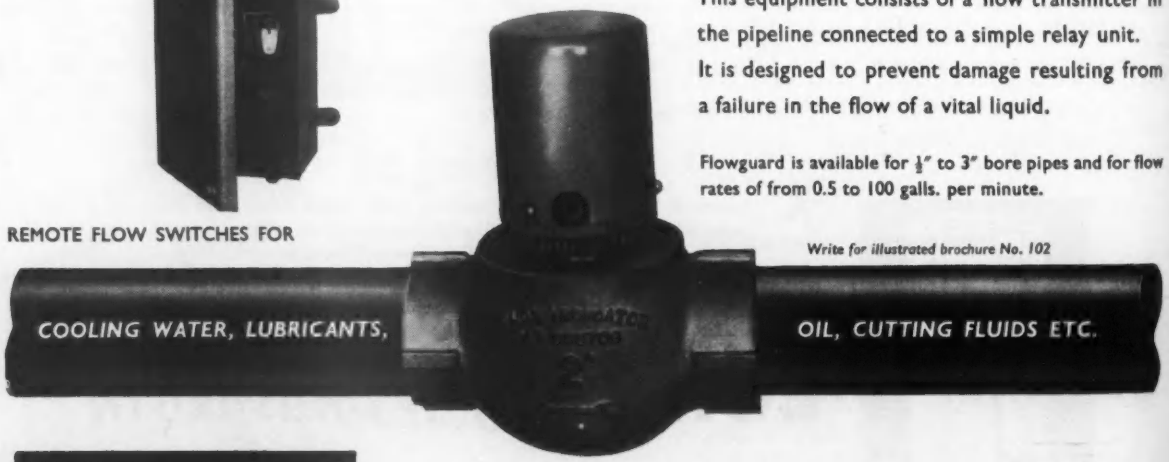

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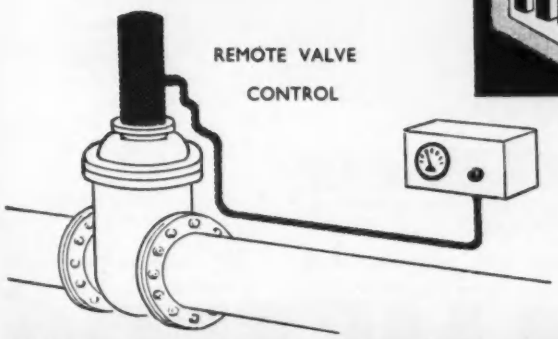

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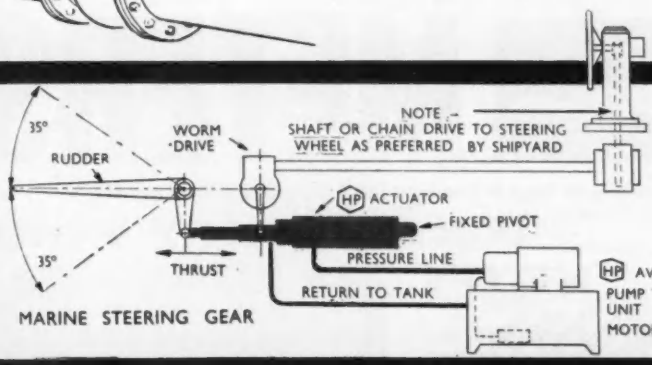

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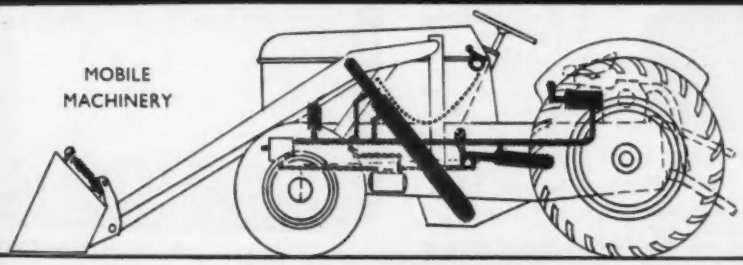

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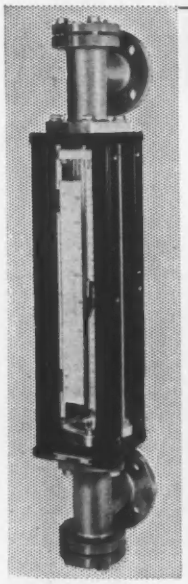

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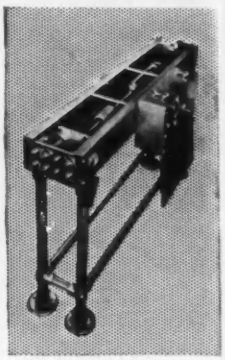

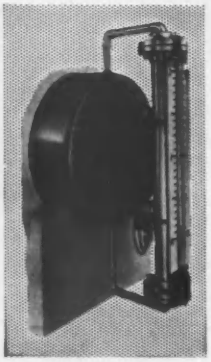

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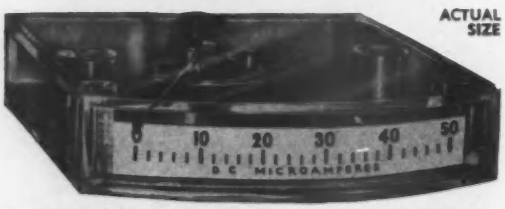

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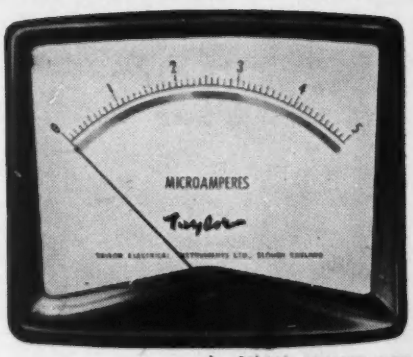

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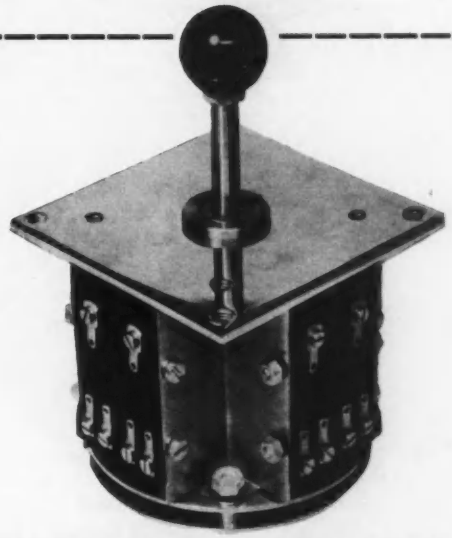

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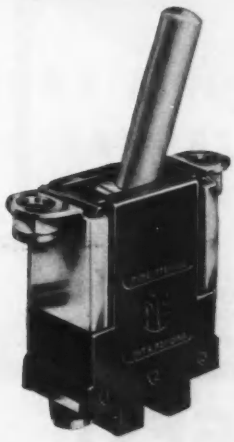

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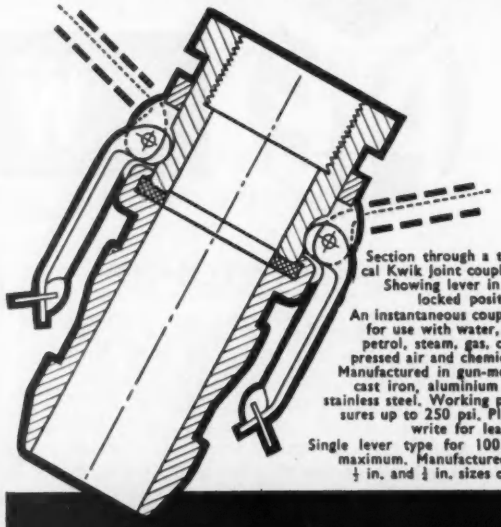

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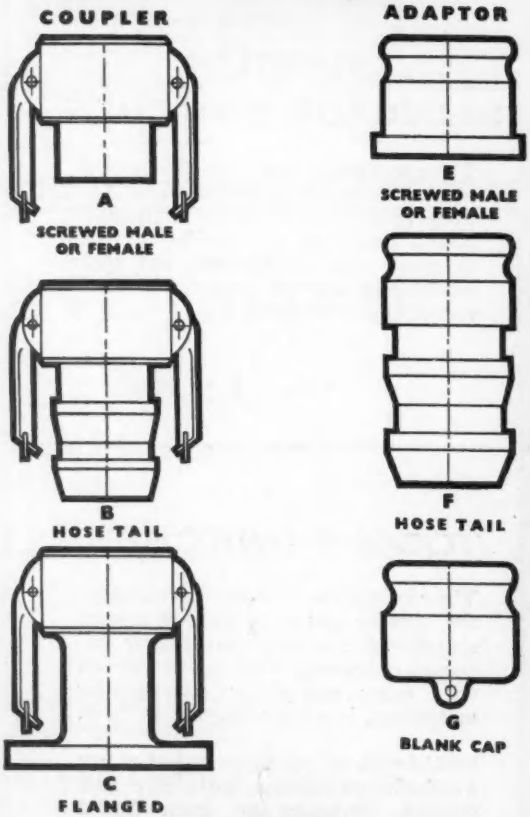

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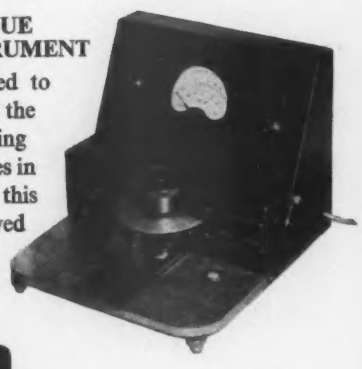

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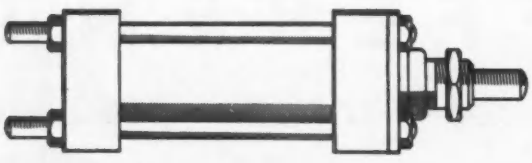

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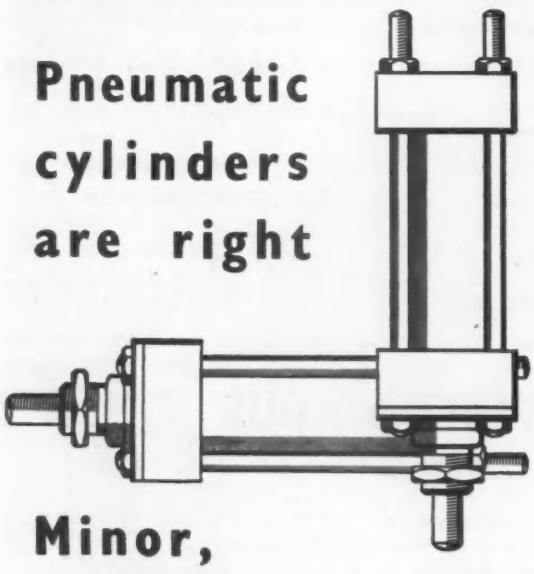

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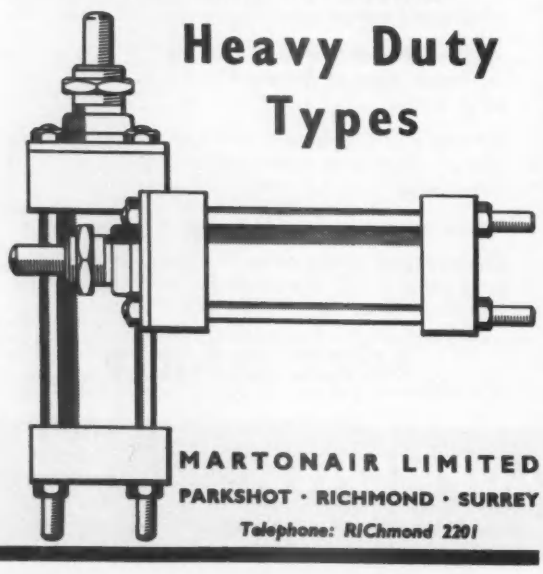

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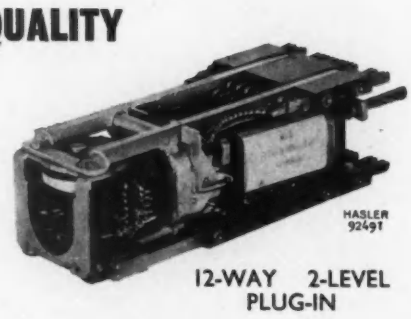

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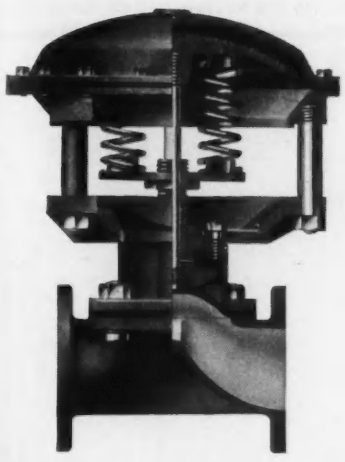

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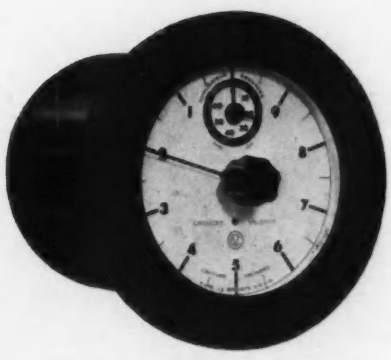
Diaphragm Valve Division · CWMBRAN · NEWPORT · MONMOUTHSHIRE

The CROUZET SYNCHRONOUS TIMER

WITH AUTOMATIC RE-SETTING



STAND 861
I.E.A. EXHIBITION
OLYMPIA

The Crouzet type 113 Timer is a panel mounting unit which is controllable by external switches or push buttons.

All connections are brought to a simple radial terminal block permitting the realisation of many different schemes according to the application.

Eleven different models are available giving a minimum time of ½ second and a maximum time of 26 hours.

By virtue of the simplicity of external connections two or more units can readily be made to operate in sequence.

The contacts are rated at 5 amps on 220V a.c.

The diameter of the recess necessary for mounting on a panel is 105 m.m. and the total depth of the unit from clock face to base is 152 m.m.

PRICE £11-10-0

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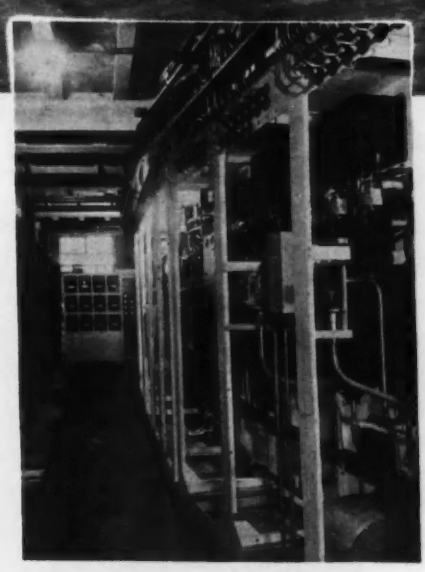
Telephone : RIChmond 6757

South Eastern Gas Board choose ELLIOTT



Rear view of the giant Control Panel.

A complete Instrumentation and Control System supplied and installed by Elliott for the Oil Gasification Plant of the South Eastern Gas Board, Isle of Grain, Kent.

Elliott-Automation takes pride in serving another of Britain's foremost industrial organisations.

THE PROCESS CONTROL DIVISION
ELLIOTT BROTHERS (LONDON) LTD
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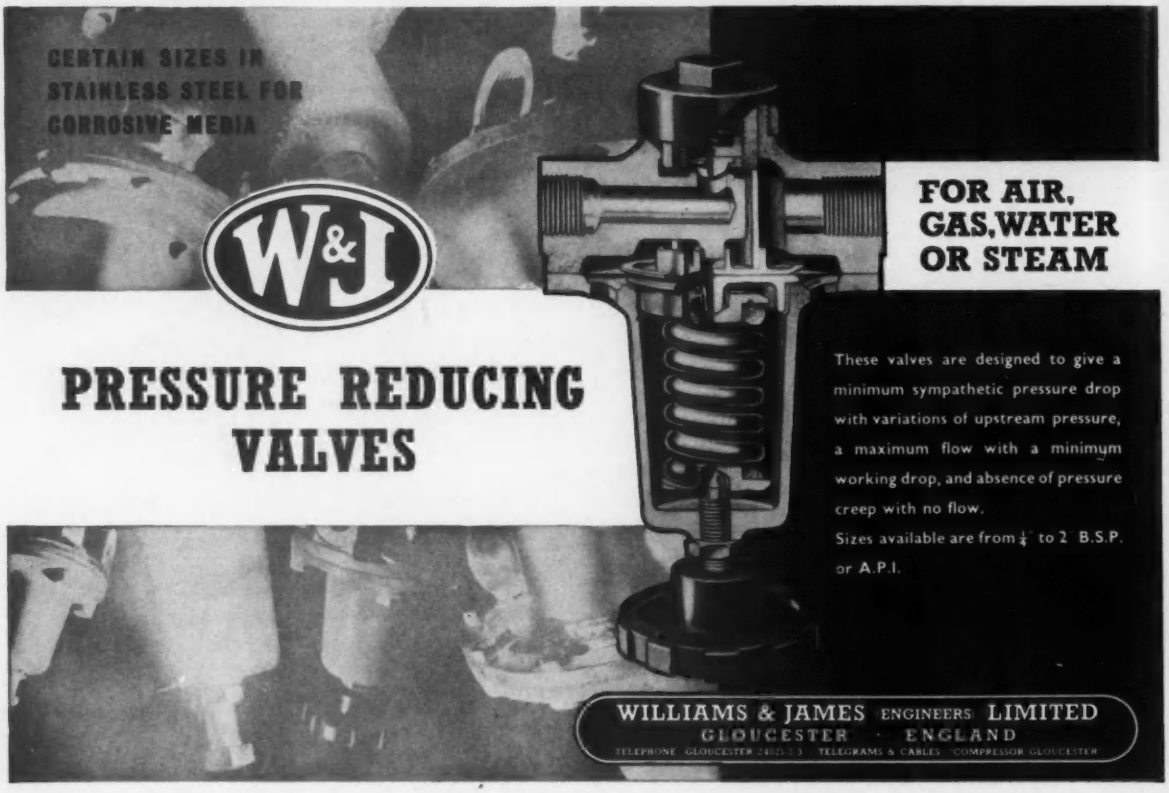
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These valves are designed to give a minimum sympathetic pressure drop with variations of upstream pressure, a maximum flow with a minimum working drop, and absence of pressure creep with no flow.
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"X" & "Y" Co-ordinate Plotting Table

CATALOGUE No. 1806

- A well-designed and robust instrument.
- A high degree of plotting accuracy is maintained with a good speed of response.
- Plotting area 15" × 10" on paper.

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BRYANS AEROQUIPMENT LIMITED

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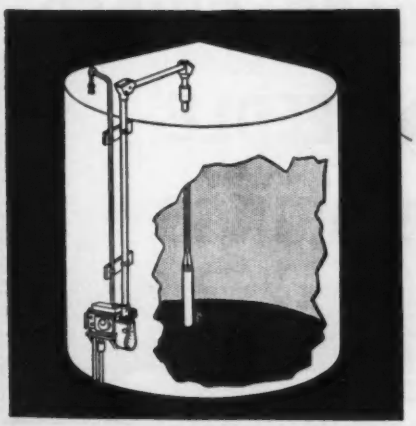
THE GILBARCO FIRTH CLEVELAND TANK GAUGE is a highly sensitive electronic device for local and remote indication of the level of liquids—or liquid interfaces—in deep tanks of all shapes and sizes. It gives continuous readings of level for liquids of any specific gravity and it is accurate within a few thousandths of an inch—this is particularly important in tanks with a large free surface area.

The instrument is suitable for use in hazardous areas and in extreme temperatures and it will operate data reduction or logging equipment. One remote indicator can be arranged to show the contents of up to 30 tanks in turn.

Routine maintenance can be carried out without taking the tank out of service.

These gauges are available to American Class 1 Group D Division 1 classification. We are shortly producing them to meet Buxton flameproof requirements.

The range of Firth Cleveland Instruments includes Electrical, Mechanical and Hydrostatic Tank Gauges, Pressure Operated Switches, and Pressure Relief Valves. We shall be happy to send you full particulars.



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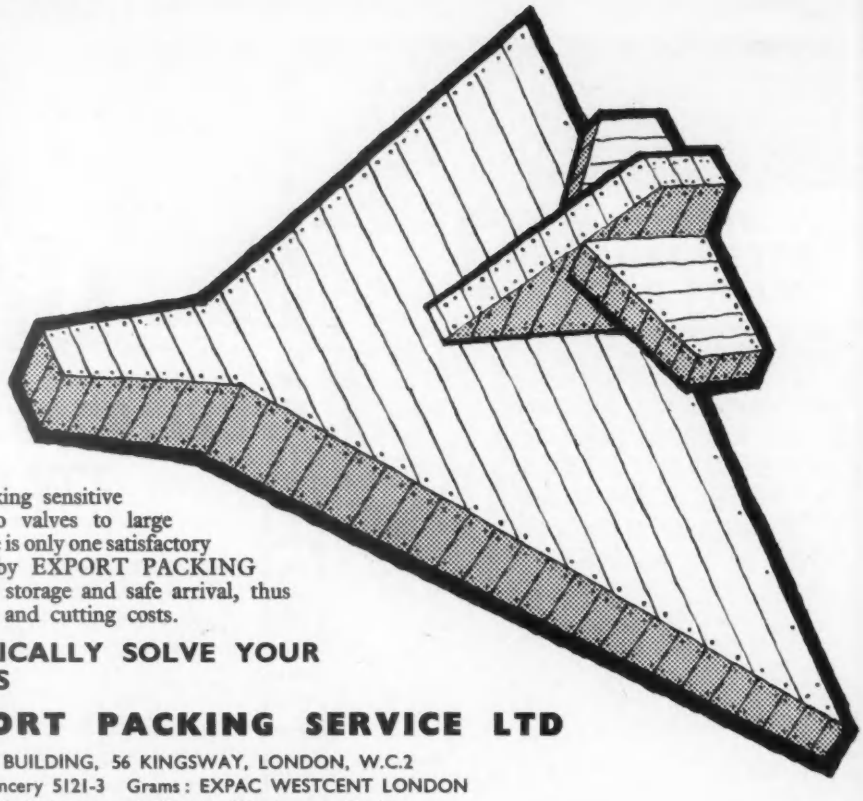

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- All needles supplied to a tolerance of ± 0.00004" on diameter.

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DAVIS of DERBY have specialised for many years in the manufacture of Buxton Certified Flameproof Enclosures

F.L.P. Enclosures are available and Enclosures can be designed to individual requirements to cover Groups I, II and III gas hazards

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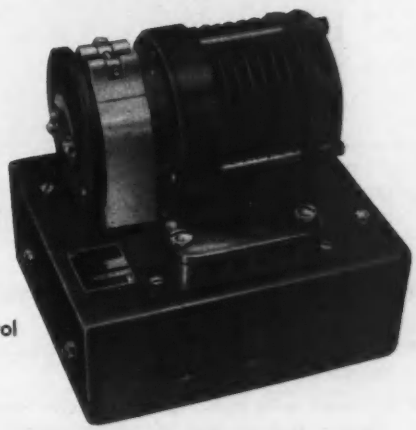

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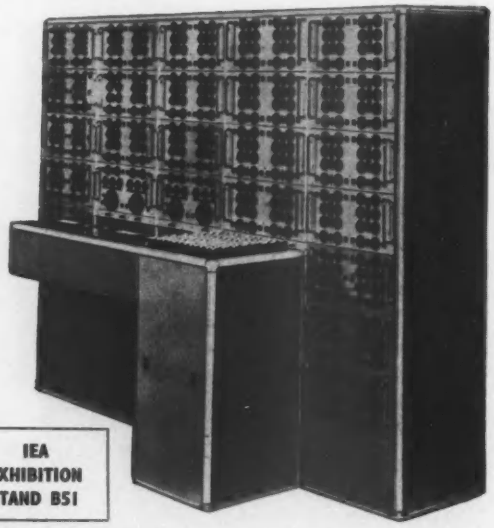

IEA EXHIBITION STAND B51

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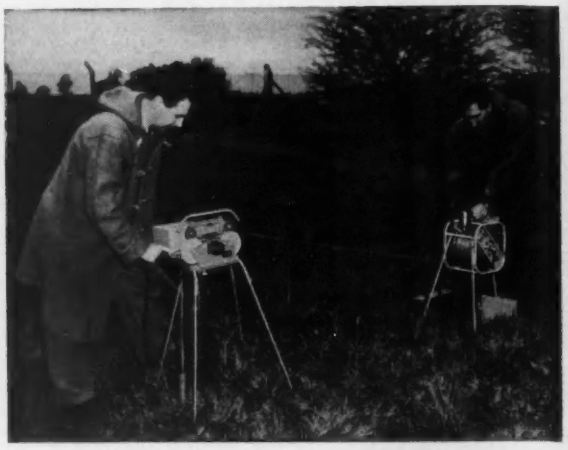

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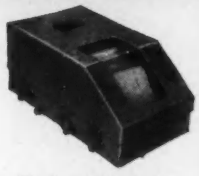
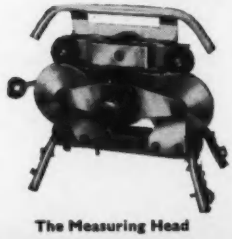
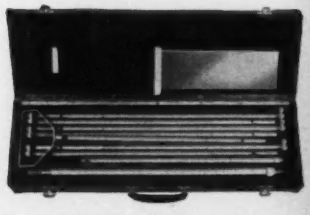


The Spark Recorder



The Measuring Head



The Transit Case with legs, probes, etc.

For full details and Specifications ask for Catalogue Sheet Nos.

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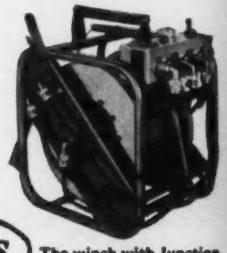

The winch with Junction Box attached

See the Hendrey Relay range at the

I.E.A. EXHIBITION, OLYMPIA, 23-28 MAY

STAND No. C113

Hendrey Relays

HENDREY RELAYS LTD., BATH ROAD, SLOUGH, BUCKS.

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moving coil panel Instruments

are now available with SQUARE FRONTS

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3 sizes are available with flange dimensions of 2.25", 3.187" and 4.50" square.
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SANGAMO WESTON

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Make Datum your starting point

- ★ Well-proved design.
- ★ Up-to-date folded section construction.
- ★ Rack tappings to suit British, U.S. and Continental equipment.
- ★ Identical front and rear frames.
- ★ Unit doors of *any* size on front or rear.
- ★ Cooling by blower, extractor fan or natural convection *without modification to rack.*

Datum **RACKS**

are engineered to your requirements

In the finest quality zinc-coated steels and finished in high-relief hammer stove enamel; other finishes available to your own particular specification.

Delivery period for most standard Racks is seven days.

Datum **METAL PRODUCTS LTD.**

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WATFORD · HERTS
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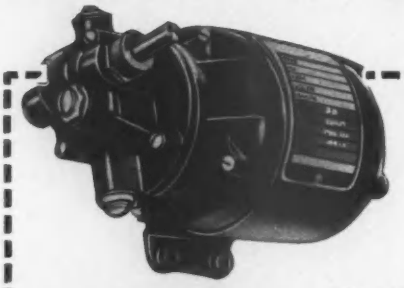
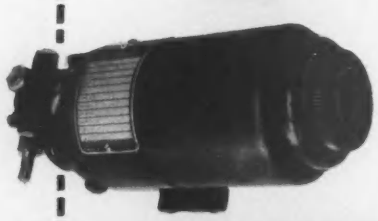
WORLD FAMOUS FRACTIONAL HORSE-POWER GEARED MOTORS





Output-shaft has 12 positions.

Integral Wormgear Reduction.

Ventilated — Drip Proof.

Vacuum Impregnated Windings.

Dynamically balanced Armatures and Rotors.

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R.P.M.	TORQUE	R.P.M.	TORQUE
600	10 oz. in.	37.5	4 lb. in.
300	16 oz. in.	25	4 lb. in.
150	24 oz. in.	18.8	4 lb. in.
100	32 oz. in.	12.5	4 lb. in.
75	36 oz. in.	9.4	4 lb. in.
50	3 lb. in.	6.25	4 lb. in.

SHADED-POLE INDUCTION GEARED MOTOR—Type 'FA'

R.P.M.	TORQUE	R.P.M.	TORQUE
216	4 oz. in.	13.5	24 oz. in.
108	7 oz. in.	9	30 oz. in.
54	10 oz. in.	6.7	35 oz. in.
36	12 oz. in.	4.5	44 oz. in.
27	15 oz. in.	3.35	3 lb. in.
18	20 oz. in.	2.25	4 lb. in.

VARIABLE SPEED GEARED MOTOR—Type 'KQ'

R.P.M	TORQUE	R.P.M.	TORQUE
200-600	9 oz. in.	12-37.5	4 lb. in.
100-300	16 oz. in.	8-22	4 lb. in.
50-150	20 oz. in.	6-16.5	4 lb. in.
32-100	32 oz. in.	4-11	4 lb. in.
25- 75	40 oz. in.	3- 8.25	4 lb. in.
16- 50	48 oz. in.	2- 5.5	4 lb. in.

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456	8 oz. in.	28.5	3 lb. in.
228	13 oz. in.	19	4 lb. in.
114	21 oz. in.	14.2	4 lb. in.
76	26 oz. in.	9.5	4 lb. in.
57	32 oz. in.	7.1	4 lb. in.
38	44 oz. in.	4.75	4 lb. in.

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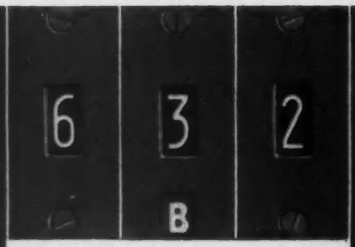

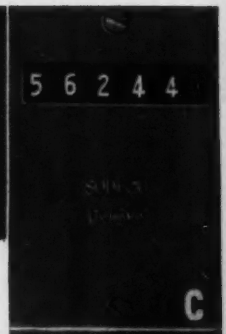

A Pre-determining Counter with Auto-reset

B Single Digit Counters which can be assembled in groups. Forward or backward counting. Auxiliary contacts for predetermining.

C Electrical Reset High Speed Counters

D Instantaneous Manual Reset High Speed Counters (10 or 25 impulses per second)

Our range of counters offers in the most compact form types for all requirements. The total full size width of the group above is only 6 inches.

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THE STONEBRIDGE ELECTRICAL CO. LTD.

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Telephone: TRAfalgar 1444

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NEW PRODUCTS & TECHNICAL LITERATURE

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521	522	523	524	525	526	527	528	529	530
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May 1960

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NOW fireye **additionally offer:**

MULTI-PURPOSE

PHOTO-ELECTRIC CONTROLS for:

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Long Range Protection. Inspection. Sorting or Counting.

- ✳ **SMOKE DENSITY INDICATORS**
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- ✳ **ELECTRONIC TIMERS**
- ✳ **HIGH TEMPERATURE PHOTOELECTRIC PYROMETERS**

STAND Q726 I.E.A. EXHIBITION

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TELEPHONE: FLEET STREET 6671 TELEGRAMS: FIREYE CENT LONDON CABLES: FIREYE LONDON
WORKS: BEDDINGTON FARM ROAD, PURLEY WAY, CROYDON

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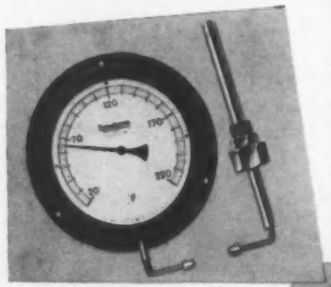
MERCURY-IN-STEEL TEMPERATURE INSTRUMENTS



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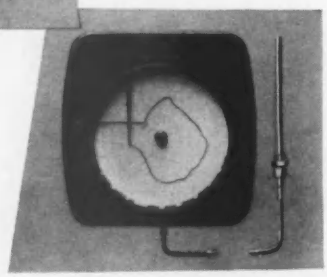

TEMPERATURE RECORDERS
Single or Dual Pen
Fixed or Portable Models

TEMPERATURE CONTROLLERS
Indicating and Non-Indicating

VISIT STAND No. Q729
Grand Hall Gallery at the I.E.A. Exhibition, Olympia
23-28 May, 1960

Also a full range of BI-METAL and VAPOUR PRESSURE Temperature Instruments
Write for details

THE BRITISH ROTOTHERM CO. LTD.
Merton Abbey, London, S.W.19. Phone: LIBerty 7661 (6 lines)
Nottingham Factory: Hollis Street, New Basford. Phone: 77847

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SEE

"SPEARETTE"
AIDS AND COMPONENTS

STAND D171
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"SPINIATURE"
PLUGS AND SOCKETS

SPEAR ENGINEERING CO. LTD.
WARLINGHAM · SURREY

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THE ELECTRONIC INDUSTRIES SOLDERING TOOL FOR THE TRANSISTOR AGE etc.

ADCOLA

(Regd. Trade Mark)

¼ BIT MODEL (Cat. No. 70)

PROTECTIVE SHIELD (Cat. No. 68)

ELECTRIC SOLDERING EQUIPMENT

Manufactured in all Volt Ranges from 6/7 to 230/50 Volt with elements Insulated from Earth

A PRODUCT FOR PRODUCTION
Designed for continual use on bench line assembly

BRIT. FOREIGN PATS. AND REG. DESIGNS ETC. Standards approved in all leading countries

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CLAPHAM HIGH STREET
LONDON SW4
Telephones
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IMPROVED CRINKLE SPRING WASHERS
in **BERYLLIUM COPPER**

Size Range
10 B.A. to ¼" B.S.F.

Satisfactorily meets the following requirements: Corrosion Resistance, Non-Magnetic, Excellent Electrical Conductivity. High Tensile Strength up to 85 tons per sq. in. Prevents damage to surfaces to be locked together. Made to Admiralty Signal and Radar Establishment Spec. A.110000—Approved by RAE/RSP. 318 & RCL. 224. *Supplied G.C.Q., A.I.D. or A.R.B. Released*

Prices and Samples on request.

Formerly marketed by
DAVID POWIS & SONS LTD.

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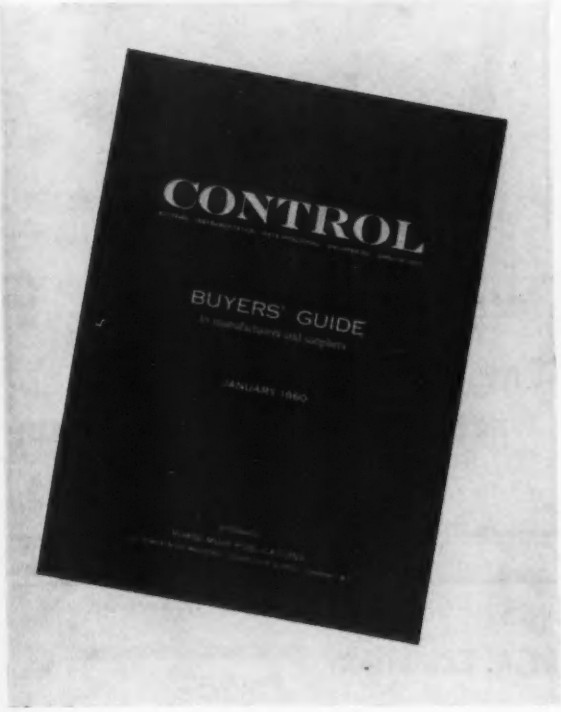
CONTROL

BUYERS' GUIDE

TO MANUFACTURERS AND SUPPLIERS



The CONTROL BUYERS' GUIDE for 1960 lists more than 1200 firms manufacturing every kind of control system and component. Published annually it is your quick reference book for addresses and control engineering components.

- - - - - - - - - - - - - - - - - - - -

Please send me the Control Buyers' Guide, for which I enclose 3/6 + 6d postage and packing.

NAME .....

ADDRESS .....

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ROWSE MUIR PUBLICATIONS LTD
THE ROWSE MUIR BUILDING,
CHARLOTTE STREET, LONDON, W1

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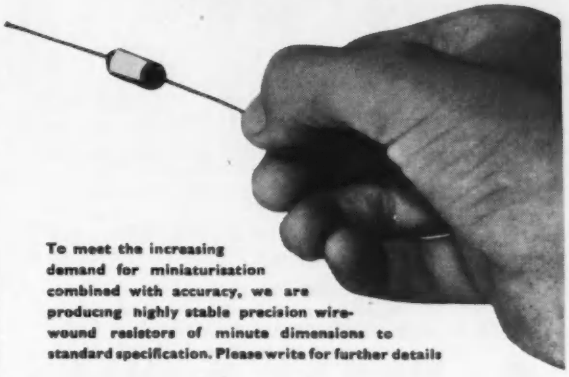
THE TREND TOWARDS

MINIATURISATION

Alma

PRECISION WIREWOUND RESISTORS
D.G.I. Approved

LEAD AGAIN



To meet the increasing demand for miniaturisation combined with accuracy, we are producing highly stable precision wirewound resistors of minute dimensions to standard specification. Please write for further details

- **DIMENSIONS** ¼" long by $\frac{5}{32}$" diameter. Axial leadouts 20 s.w.g. tinned copper wire 2½" long.
- **Standard Tolerances set at 20°C.:** 1%, 0.5%, 0.25% and 0.1%
- **ANY VALUE** can be supplied in the Resistance Range 100 ohms to 500K ohms.
- **Rating** ¼ watt.
- **Guaranteed Temperature Coefficient better than 0.002% per °C. over the whole resistance range.**
- **Specially selected wire is sealed against humidity in a resin which can withstand temperatures of over 150°C.**
- **Precision Component designed and manufactured for consistent accuracy.**

Standard products include 2W, 1W, ½W and ¼W precision wirewound resistors in the range 0.1 ohms to 10 megohms. Higher values can also be produced to order.

We are exhibiting on

STAND F268

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Alma **COMPONENTS LTD.**

551 HOLLOWAY ROAD, LONDON, N.19
Telephone: ARCHWAY 0014/5

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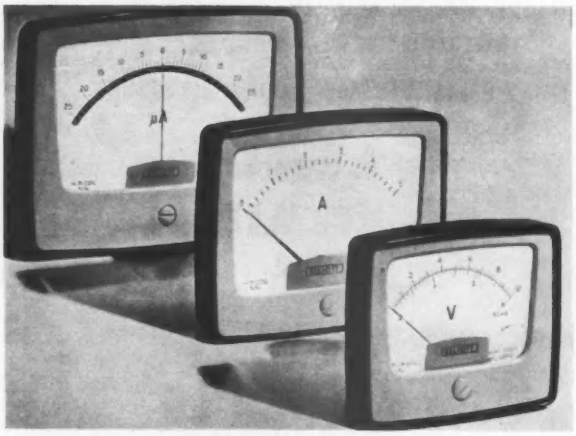
Small in size . . .
but "ELLIOTT-ACCURATE"

The introduction of these three new models completes the famous Elliott range of miniature instruments. Small in size . . . crystal clear in indication and consistently Elliott-accurate!



Electrical Measurement Division

ELLIOTT BROTHERS (LONDON) LTD

Century Works, Lewisham, London, SE13 · Tideway 1271

A member of the Elliott-Automation Group

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Type LP 2

PENNY & GILES

MUDEFORD · CHRISTCHURCH · HANTS

TELEPHONE HIGHCLIFFE 2855

RECTILINEAR POTENTIOMETERS

FOR REMOTE INDICATION AND RECORDING OF DISPLACEMENT

STROKE LENGTHS

Up to 9 inch for Type LP 2
Up to 24 inch for Type LP 1

TWO RESISTANCE ELEMENTS

AMBIENT TEMPERATURES

Available for use in the following ranges
−50°C to + 85°C
−50°C to +150°C
−50°C to +250°C

RESOLUTION of 0·001 inch can be achieved

WRITE FOR DATA SHEETS

Also manufacturers of potentiometers in size 11 and size 15 synchro mountings.
Single and multi-gang. Single and multi-turn.

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SINCE 1880

Makers of Precision Gears

All types up to 8″ diameter
10 to 64 D. P.

Send your enquiries to:—

OUR NEW FACTORY

G. W. EVERY & SONS LTD.

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Telephone: Bletchley 2476

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I.E.A. Exhibition

Olympia 23rd-28th May, 1960.
Stand G. 317

FLO-STAT

Prototypes of new Flostat developments.

Examples of novel schemes of automatic flow control.

The full range of Flostat flow controllers and flow governors.

The two new Flostat Minors.

GAP FLOW Meter

Gapmeters—including recent additions to the range, also special adaptations.

Flo-scan photo-transistor flow alarm.

Flow control advisory service.

FLO-SCAN

Photographs, drawings and specimens of Instrument Panels, Plant Layouts and Equipment designed for specialised applications.

G. A. PLATON LTD.

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Telegrams: GAPMETER, CROYDON.

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could Screen Printing solve them?

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As Europe's leading supply house we offer a complete service to industry. Our range of hand, semi- and fully automatic machines can handle anything from transistors to 20 ft. banners. Our technicians will be pleased to discuss your problems.

IMPORTANT

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SCREEN PROCESS SUPPLIES LIMITED

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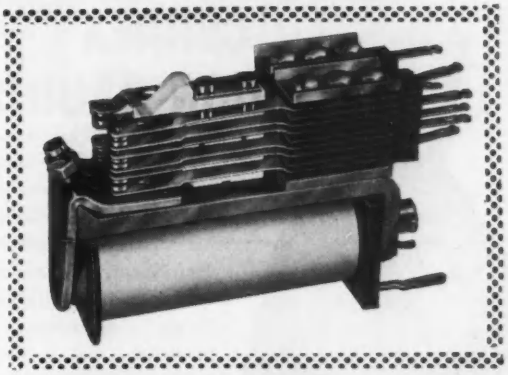
RELAYS

TO SPECIFICATION



POST OFFICE TYPE 3,000 and 600 RELAYS

Specialists in tropical and Services jungle finish.
Guaranteed to full A.I.D. and I.E.M.E. standards.

Prompt Deliveries. Prototypes within 24 hours.

Approved by the Admiralty, Post Office and U.K.A.E.A. All relays guaranteed made in our own works. P.T.F.E. insulation now available

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Manufacturers to H.M. Government Departments and leading Contractors
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PRECISION GEARS

GEAR HEADS

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SPURS, HELICALS
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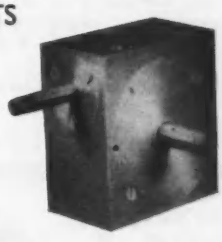

SMALL PRECISION GEARS
UP TO ADMIRALTY CLASS I
NORMAL RANGE 24 TO 100 D.P.
IN ANY RECOGNISED MATERIAL

WRITE FOR OUR BROADSHEET.
CONSULT US FOR THE SOLUTION
OF YOUR GEAR PROBLEMS

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MOUNT EPHRAIM WORKS
ROYAL TUNBRIDGE WELLS KENT
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"CORREX" TENSION GAUGES

The only instrument solely designed for accurately measuring tension on *Relays*, *Contacts*, *Switchgear*, and electrical apparatus of all kinds. Gauge measures in grammes, and a large range of sizes is produced to cover from 0.3–2,000 grammes.
Swiss made and guaranteed.

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Telephone TERMINUS 8866 (P.B.X.)

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TEST SIEVES
For Accuracy!

POCKET INTERCHANGER SIEVES

'ENDROCK' TEST SIEVE SHAKER

TEST SIEVES
B.S. 410: 43 U.S. Standards and Tyler Equivalents

We operate a Recovering Service

Consistent mechanical action—
saves valuable time of skilled personnel

ENDECOTTS (FILTERS) LTD. Phone: LIBerty 8121/2/3
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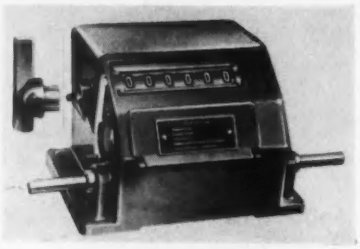

IMPULSE
REVOLUTION
STROKE
COUNTING

All types available for :
Electrical or mechanical zero reset.
Predetermination of 1, 2 or 4 independent circuits during single counting process.
Projection or flush mounting.

Also :
PRINTING AND INDICATING COUNTERS
over 300 types

RADIATRON
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RICHMOND, SURREY
Telephone: RICHMOND 3285

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If you demand air-cylinders which are . . .

PNEU IC CYLI RS

Made entirely from non-corrodible materials.
Designed to include extra-stiff piston rods when required.
Fitted with replaceable bronze rod bearings, protected by external wiper seals.
Available cushioned or non-cushioned from 1" to 14" bore, in 9 different mountings and strokes up to 12 feet.

then you will want to fit.

MIDLAND PNEUMATIC LTD
NEW CROSS · WOLVERHAMPTON

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Also complete range of PILOT VALVES, CONTROL VALVES and FITTINGS

Write for comprehensive catalogue giving full details.

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Acknowledged Supreme by Engineers the world over

Manufactured in the Beckman Modern Factory in Glenrothes, Fife, Scotland, and Distributed by WINSTON ELECTRONICS LIMITED.

A one turn to 40 turn Precision Potentiometer now available for every requirement.

HELIDEL DELAY LINES. DUODIAL TURNS COUNTING DIALS. DIGIDIAL TURNS COUNTING DIALS.

Some typical examples of Helical Potentiometers

SERIES	A	AJ(7220)	B	C	E	G	J(5600)	L(5700)
Number of turns	10	10	15	3	40	1	1	1
Diameter, inches	1-13/16	7/8	3-5/16	1-13/16	3-5/16	1-5/16	1·875	3
Length of case, inches	2	1-1/2	2-13/16	1-9/64	6-1/64	47/64	1·041	1
Shaft diameter, inches (nom.)	1/4	1/8	1/4	1/4	1/4	1/4	1/4	1/4
Coil length, inches (approx.)	46	18	140	14	374	3·1	5	8·2
Mechanical rotation	+4° 3,600°−0°	+10° 3,600°−0°	+4° 5,400°−0°	+4° 1,080°−0°	14,400°(+4°/−0°)	360° Cont	360° Cont	360° Cont
Electrical rotation	+4° 3,600°−0°	+10° 3,600°−0°	+4° 5,400°−0°	+4° 1,080°−0°	14,000°(+4°/−0°)	352±2°	356°±1	358°±1°
Resistance range, ohms	5 to 450K	25 to 100K	40 to 1 meg	5 to 130K	100 to 2·5 meg	5 to 30K	35 to 80K	50 to 163K
Best pract. resist. tol. (a)	±1%	±2·5%	±1%	±1%	±1%	±1%	±1%	±1%
Best pract. linearity tol. (b)	±0·05%	±0·05%	±0·01%	±0·1%	<1KΩ ±0·05% >1KΩ ±0·01%	<200Ω ±1% >200Ω ±0·25%	<50Ω ±1% >5KΩ 0·15%	±0·1%
Max. noise millivolts (c)	250	250	250	250	250	100	100	100
	2K & up	1K & up	5K & up	500 & up				
Watts at 25°C ambient (d)	6·9	2·8	13·8	4·1	27·5	2·8	4·8	6·9
Watts at 40°C ambient	5	2	10	3	20	2·0	3·5	5
Weight, oz. (approx.)	4·4	1	13	2·5	21	2	3·2	5·9
Max. starting torque, oz. in.	2	0·7	2·7	1·8	3·5	0·7	1·7	1·3
Max. running torque, oz. in.	1·5	0·6	2	1·3	2·5	0·5	0·8	0·5
Moment of inertia, gm., cm²	18	0·3	200	7	400	2·8	5	8·6
Max. taps	28	32	80(e)	14	100	8	21	33
Min. distance between taps	20°±1°	45°±2°	15°±1°	20°±1°	15°±1°	36°±1°	15°±1°	10°±1°
Max. ganged sections	3	consult factory	3	3	None	None	8	8
Life expectancy, shaft revs.	>2,000,000	>2,000,000	>2,000,000	>2,000,000	>2,000,000	>2,000,000	>2,000,000	>2,000,000

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SYSTEMS & APPLICATIONS

WHO'S WHO

BUYERS' GUIDE

ON 15 SEPTEMBER

CONTROL's first INDUSTRY GUIDE AND DIGEST

will be published. As well as summarizing the year's new and important control systems, components and instrumentation, it will include a revised and enlarged Buyers' Guide, and the first-ever specialized Who's Who in the field of control engineering.

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AEI

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INSTRUMENTATION DIVISION
HARLOW, ESSEX

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Engineers with an appreciation of Statistical Methods and capable of original thought are required to carry out Optimisation Investigations on Industrial Processes.

A Mathematician is required to devise the necessary computational procedures and to prepare or supervise the preparation of Digital Computer Programmes.

Each investigation will involve obtaining an understanding of the Process under study; formulating a programme for the investigation; making the necessary Process measurements using data-logging equipment; analysing the results using a digital computer and producing a specification for an optimum control scheme which may include a Process Control Computer. Previous experience in Chemical Engineering, Control Engineering or any work on Industrial Plant will be useful.

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WORKS ENGINEER
required for progressive company
manufacturing industrial
ELECTRONIC INSTRUMENTS

Applicants must have experience of manufacture of electronic and electro mechanical equipment and a sound knowledge of production engineering techniques.

Attractive salary. Excellent prospects for advancement. Age 30/45.

Apply to: Works Manager
FIELDEN ELECTRONICS LTD.
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The Company has a long history of success with Analogue Computers and is constantly seeking new applications and improved designs. The laboratory is equipped with up to date instrumentation and every opportunity exists for exercising individual initiative.

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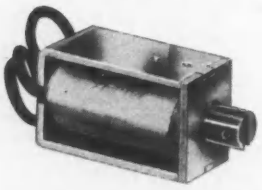

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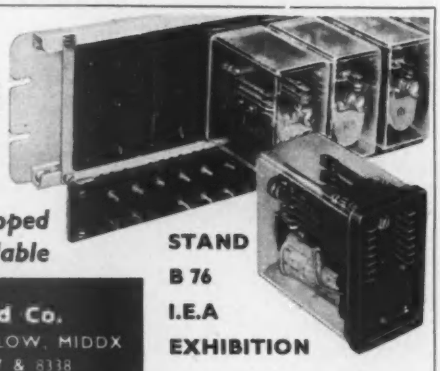

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